

**NASA
Technical
Memorandum**

NASA TM-86461

**INDUCED ENVIRONMENT CONTAMINATION MONITOR —
PRELIMINARY RESULTS FROM THE SPACELAB 1 FLIGHT**

Edited by E. R. Miller
Space Science Laboratory

August 1984



National Aeronautics and
Space Administration

George C. Marshall Space Flight Center

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. NASA TM-86461	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE Induced Environment Contamination Monitor — Preliminary Results from the Spacelab 1 Flight		5. REPORT DATE August 1984	
7. AUTHOR(S) Edited by E. R. Miller		6. PERFORMING ORGANIZATION CODE	
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		8. PERFORMING ORGANIZATION REPORT #	
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546		10. WORK UNIT NO.	
		11. CONTRACT OR GRANT NO.	
		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum	
		14. SPONSORING AGENCY CODE	
15. SUPPLEMENTARY NOTES Prepared by Space Science Laboratory, Science and Engineering			
16. ABSTRACT <p>The STS-9/Induced Environment Contamination Monitor (IECM) mission is briefly described. Preliminary results and analyses are given for each of the 10 instruments comprising the IECM. The final section presents a summary of the major results.</p>			
17. KEY WORDS Spacecraft Contamination, Space Shuttle, Spacelab, Spacecraft Environment		18. DISTRIBUTION STATEMENT Unclassified — Unlimited	
19. SECURITY CLASSIF. (of this report) Unclassified	20. SECURITY CLASSIF. (of this page) Unclassified	21. NO. OF PAGES 44	22. PRICE NTIS

Page intentionally left blank

Page intentionally left blank

TABLE OF CONTENTS

	Page
I. INTRODUCTION (E. R. Miller)	1
II. AIR SAMPLER (P. N. Peters, H. B. Hester, W. Bertsch, T. Marr)	4
III. CASCADE IMPACTOR (D. A. Wallace, B. J. Duncan)	11
IV. OPTICAL EFFECTS MODULE AND PASSIVE SAMPLE ARRAY (R. C. Linton)	13
V. QUARTZ CRYSTAL MICROBALANCE SURFACE CONTAMINATION MEASUREMENTS (J. A. Fountain and D. McKeown)	21
VI. CAMERA/PHOTOMETER (J. K. Owens, K. S. Clifton)	32
VII. MASS SPECTROMETER (G. R. Carignan, E. R. Miller)	36
VIII. SUMMARY (E. R. Miller)	41

TECHNICAL MEMORANDUM

INDUCED ENVIRONMENT CONTAMINATION MONITOR — PRELIMINARY RESULTS FROM THE SPACELAB 1 FLIGHT

I. INTRODUCTION

The fourth flight of the Induced Environment Contamination Monitor (IECM) occurred aboard the Columbia orbiter on the STS-9 mission and provided the opportunity to measure the molecular and particulate environment of the Space Shuttle with the large Spacelab-1 (SL-1) payload. The SL-1 payload consisted of a long manned module and one pallet configuration. The IECM was located on the pallet near the orbiter rear bulkhead and surrounded on 3 sides by science experiments (Fig. I-1).

The IECM instrument complement remained the same as on previous flights on STS-2, -3, and -4: (1) Humidity monitor and (2) dew point hygrometer, for water vapor and air temperature measurements; (3) air sampler, for sampling of hydrocarbons, HCl, and NO products in the cargo bay; (4) cascade impactor, for aerosol measurements; (5) optical effects module; and (6) passive sample array, for optical contamination effects and particle accumulation measurements; (7) temperature-controlled and (8) cryogenic quartz crystal microbalances, for molecular mass accumulation measurements; (9) camera/photometer, on-orbit particulates and light background measurements; and (10) mass spectrometer, for measurements of quantity and mass of molecular flux.

Results of the earlier flights have been reported, References 1 and 2, and a more complete description of the IECM instruments and system was reported in Reference 3.

The IECM was installed on the Spacelab-1 pallet in the operations and checkout (O&C) building at Kennedy Space Center (KSC) in August 1982. The Spacelab payload was installed in the Orbiter in the Orbiter Processing Facility (OPF) on about August 19, 1983. The flight of STS-9 began at 1600 UT on November 28, 1983, and ended at 0048 UT on December 9, 1983.

Columbia was launched to an altitude of 250 km with an inclination angle of 57 deg. The major attitudes attained during the mission until IECM experienced an electronic failure at 177 hr mission elapsed time (MET) are depicted in Figure V-1.

Measurements and results are presented in Sections II through VII and a summary of results is presented in Section IX. Measurements and results from the Humidity Monitor and Dew Point Hygrometer are not included in these sections due to the on-orbit failure of IECM that prevented recording of descent and postlanding data. During ascent, the humidity and dew point remained below sensible levels.

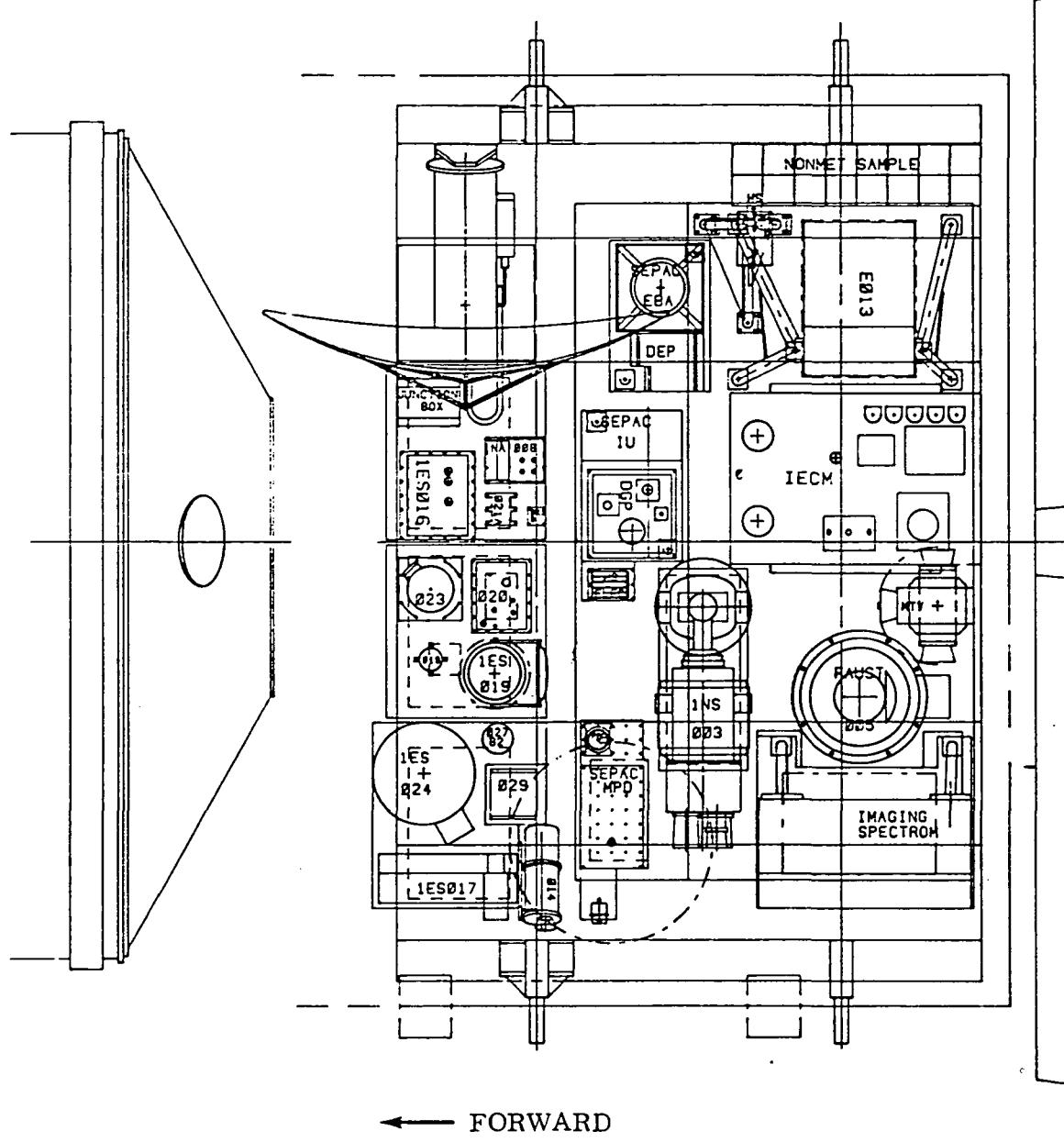


Figure I-1. SL-1 plan view showing location of IECM and science instruments on the Spacelab pallet

REFERENCES

- I-1. Miller, E. R. (Editor): STS-2, -3, -4 Induced Environment Contamination Monitor (IECM) Summary Report. NASA TM-82524, February, 1983.
- I-2. Miller, Edgar R.: Update of Induced Environment Contamination Monitor Results. AIAA-83-2582-CP, AIAA Shuttle Environment and Operations Melting, October 31-November 2, 1983.
- I-3. Miller, Edgar R. and Rudolf Decher (Editors): An Induced Contamination Environment Monitor for the Space Shuttle. NASA TM-78193, August, 1978.

II. AIR SAMPLER

By P. N. Peters, H. B. Hester, W. Bertsch*, and T. Marr*

The air sampler, which has been described in detail elsewhere [1], performs six separate sampling operations: ground sampling for condensibles prior to flight readiness, two integrated samplings during the first 70 sec of ascent (pumped through adsorbents in one container and past reactive surfaces in another container), one "grab sample" (an evacuated bottle containing reactive surfaces which is opened while at higher altitudes), and two descent samplings (integrated sampling for condensibles and reactives).

The ground sample, taken at the last close out, exhibited components that correspond to previously established profiles, consisting primarily of hydrocarbons found in urban environments. Many substances found in the early part of the flight samples are identical but the ground sample contains some additional substituted aromatic hydrocarbons, such as xylenes. Total mass of organic material in this ground sample was approximately 1.0 μg from approximately 1.5 std. liters of sampled air.

The chromatogram for the ground sample does not exhibit the hump observed in the chromatograms for the ascent and descent samples. As described later, these humps are characteristic of lubricating oils. After associating the humps with lubricating oil, we learned that the IECM had been exposed to oil drops from an overhead crane prior to flight. The absence of the hump in the ground sample, which should have been taken after exposure to lubricating oil from the crane, seems to contradict an assumption that this was the source; no other lubrication leaks have been reported to us.

The ascent sampling operations occurred as scheduled. A subsequent program with the Data Acquisition and Control System prevented pumping and valve operations during descent, however, the valves for the descent bottles were previously opened near the end of ascent in order to vent these bottles into space and avoid the possibility of a slow, continuous leak while in orbit. Thus, descent data was obtained as the bottles refilled during descent, the only disadvantages are that less volume was sampled and the bottles were not sealed completely until later ground operations commanded the valves close.

Residual gas analyses were performed on gases trapped in bottles prior to sample removal. The ascent condensable sampling bottle, which contains the high integrity metal-to-metal seals to assure no loss of condensibles while in orbit, trapped an appreciable quantity of hydrogen as well as other gases shown in Table II-I. Only on STS-4 and this flight were the high integrity seals functioning properly and in both cases hydrogen was found in the residual gases of the ascent bottle (3.8 percent hydrogen for STS-4 and 15.2 percent for this flight). Blow by from the small pyro charges used to actuate these valves has been suggested as the hydrogen source by several groups familiar with these valves. Postflight helium leak checks from the pyro chamber to both inlet and outlet ports of both valves gave negative results for sensitivities better than 10^{-10} std. cc sec⁻¹. Thus, if blow by resulted, it probably occurred during the brief period of firing. Analyses of gases produced by firing a pyro charge indicate that sufficient hydrogen is produced to account for the amount observed, but the presence of oxygen in the gases trapped in the bottle with the

*Department of Chemistry, The University of Alabama, Tuscaloosa.

hydrogen is puzzling. Both hydrogen and oxygen would not have resulted as pyro by-products, and other residual volumes within the sampling bottle should have contained pure dry nitrogen used in a glove bag while installing the adsorbents or dry helium purge gas used while sealing the bottles. Presumably any air that may have exchanged places with gases in the bottle during ground testing would have also been pumped during ascent. Negligible amounts of helium were observed. Other data from the Shuttle's aft compartment, preflight measurements, and postflight analyses did not support assumptions of hydrogen in the cargo bay, which should have contained a dry nitrogen purge gas. If blow by is occurring, some undetermined corrections may be necessary for this bottle. The pyro products appear to be mostly hydrogen, CO₂, methane, water, etc. and not some of the major compounds observed.

Analysis by GC/MS of the ascent condensibles baked from the Tenax GC adsorbents provided the results shown in Figure II-1 and Table II-2. The "hump" occurring late in the chromatogram consists of unresolved hydrocarbon type materials typical of lubricating oils. The low volatility of this hump suggests liquid was sprayed onto the inlets to the adsorbents, since gas phase transport would be unlikely. A pyro source for the hump is discounted because the pyro products are inappropriate and the descent bottle, which contains no pyro valves, exhibits a similar hump. The total masses reported do not include the hump in each case since it has no similarity to the standard calibration used (obviously the area under the hump is large, suggesting an appreciable mass). Calibrations utilized a gasoline standard and estimates of air throughput were made on the basis of previously measured pumping system parameters.

Analysis by GC/MS of the descent condensibles was similarly accomplished except air throughput was not determined since the pumping system did not function (absence of command signals during descent). These results are shown in Figure II-1 and Table II-3.

GC/MS analyses of control samples stored in the laboratory showed only small changes that might be expected from the necessary long term storage of the Tenax GC; the large backgrounds observed in controls for earlier flights were eliminated by not including any carbonaceous adsorbents on this flight.

Quadrupole mass spectrometer analyses of the gases from the bottles prior to opening and removal of samples indicated small peaks at 64 amu (less than observed for STS-3) and discolorations were found on silver samples exposed in these bottles. The discolored samples exhibited weak sulfur peaks in X-ray emission spectra obtained by energy dispersive spectrometry. The only other weak peaks observed were associated with polishing compounds used in sample preparations and were present before and after flight. No similar discolorations were observed on samples left in the laboratory during the period of flight. The source of this apparently low level of SO₂ is still not known.

REFERENCE

1. Peters, P. N. and Hester, H. B.: Air Sampler. In An Induced Environment Contamination Monitor For the Space Shuttle, NASA TM-78193, Edited by E. R. Miller and R. Decher, August 1978.

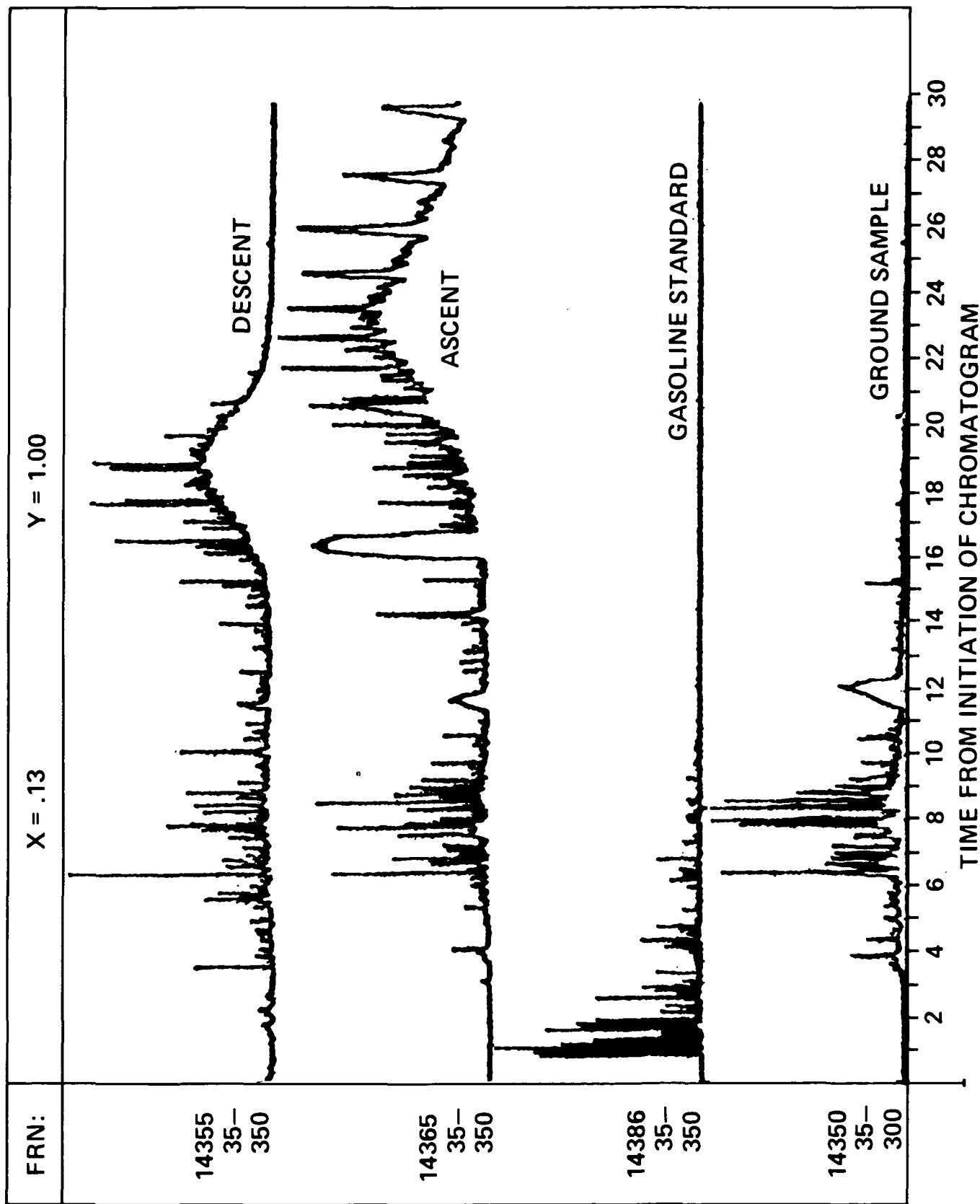


FIGURE II-1. CHROMATOGRAMS FOR STS-9/SL-1.

TABLE II-1. RESIDUAL GASES SEALED IN THE ASCENT CONDENSIBLES BOTTLE ON STS-9/SL-1*

Hydrogen	15.22%
Helium	0.02%
Oxygen	11.71%
Carbon Monoxide	11.84%
Carbon Dioxide	5.40%
Methane	0.58%
Argon	0.59%
Nitrogen	54.64%

*Determined by Tom Schehl of the Microchemical Analysis Branch, NASA/KSC, by the same techniques used in aft fuselage gas analysis. Mr. Schehl further states: "The high concentration of carbon monoxide, carbon dioxide and methane are indicative of pyrotechnic ingestion. Assuming the same product distribution utilized for analysis of the aft fuselage gas samples the hydrogen content would be reduced by 5.6 percent." It should be noted that assumption of the same pyro product distribution may not be valid, since different valves are used in our air sampler compared to those used in the aft fuselage.

TABLE II-2. SPECIES FROM ASCENT CONDENSIBLES BOTTLE

Peak Number	Area Percent	Amount in 10^{-9} g Per Substance	Substance Identity
1	3.8	45	hexamethylcyclotrisiloxane
2	1.2	14	cyclic hydrocarbon
3	4.1	49	unidentified
4	2.1	25	low MW alcohol or ketone
5	8.4	100	C ₇ branched alkane
6	2.8	34	C ₇ branched alkane
7	0.2	2	unidentified
8	1.1	13	C ₈ branched alkane
9	1.0	12	C ₉ branched alkane
10	2.1	25	octamethylcyclotetrasiloxane
11	2.5	30	branched alkane
12	4.9	59	aromatic ketone (1-phenyl ethanone?)
13	3.0	36	branched alkane (C ₉ ?)
14	2.9	35	branched alkane (C ₁₀ ?)
15	2.8	33	branched alkane
16	1.3	16	branched alkane
17	2.6	31	(alcohol or diol?)
18	1.6	19	branched alkane
19	3.6	43	naphtalene
20	1.0	12	(ester?)
21	4.0	48	unidentified
22	1.0	12	tridecane
23	1.5	18	tetradecane
24	0.9	11	ester or diester
25	1.7	20	unidentified
26	3.0	36	branched alkane
27	2.3	28	substituted aromatic comp.
28	1.0	12	unidentified
29	2.0	24	unidentified
30	5.6	67	branched alkane
31	1.4	18	unidentified
32	2.8	34	brnached alkane
33	4.7	56	branched alkane
34	3.5	42	branched alkane
35	3.7	44	branched alkane
36	4.7	56	branched alkane
37	2.5	32	branched alkane
38	1.0	12	branched alkane

Total mass of organic material in this sample was approximately $1.2 \mu\text{g}$ (1.2×10^{-6} g). Volume sampled ~ 250 std. cm^3 . Please note that this does not include the "hump" toward the end of the chromatogram which consists of unresolved hydrocarbon type materials typical of lubricating oils.

TABLE II-3. SPECIES FROM DESCENT CONDENSIBLES BOTTLE

Peak Number	Area Percent	Amount in 10^{-9} g Per Substance	Substance Identity
1	0.6	21	unidentified
2	2.5	87	branched alkane
3	0.2	7	branched alkane
4	0.9	32	branched alkane
5	1.3	46	C_7 branched alkane
6	0.6	21	branched alkane
7	0.6	21	branched alkane
8	0.8	28	unidentified
9	1.4	49	C_9 branched alkane
10	2.7	93	octamethylcyclotetrasiloxane
11	0.7	25	branched alkane
12	0.7	25	branched alkane
13	0.7	25	branched alkane
14	0.5	18	branched alkane
15	3.0	105	branched alkane
16	0.3	10	branched alkane
17	2.5	88	branched alkane
18	1.4	49	branched alkane
19	1.6	56	branched alkane
20	1.6	56	branched alkane
21	0.9	32	unidentified
22	0.7	25	branched alkane
23	0.6	21	unidentified
24	0.6	21	tridecane
25	0.6	21	ester or diester
26	0.3	11	unidentified
27	4.7	165	phtalate isomer (plasticizer)
28	0.9	32	branched alkane
29	4.1	143	phtalate isomer (plasticizer)
30	0.6	21	unidentified
31	1.6	56	branched alkane
32	0.7	25	anthracene

TABLE II-3. (Concluded)

Peak Number	Area Percent	Amount in 10^{-9} g Per Substance	Substance Identity
33	1.0	35	carboxylic acid
34	1.7	60	branched alkane
35	0.8	29	unidentified
36	0.7	25	branched alkane
37	1.0	35	heptadecane
38	1.4	49	branched alkane
39	3.8	133	phtalate (dibutyl ?)
40	1.3	46	unidentified
41	6.5	228	unidentified
42	1.9	67	unidentified
43	0.9	32	branched alkane
44	0.3	16	branched alkane
45	0.7	25	branched alkane
46	0.8	29	unidentified
47	3.2	112	branched alkane
48	0.3	11	branched alkane
49	0.5	16	unidentified
50	3.8	133	alkane (branched ?)
51	0.4	14	branched alkane
52	4.1	144	alkane (branched ?)
53	6.4	224	alkane (branched ?)
54	8.8	308	alkane (branched ?)
55	8.6	301	alkane (branched ?)
56	0.2	7	branched alkane

Total mass of organic material in this sample is about 3.5 μ g, not including the "hump" at the end of the chromatogram. Volume sampled is larger than for ascent but not known since valves were not commanded as scheduled.

III. CASCADE IMPACTOR

D. A. Wallace* and B. J. Duncan

The Cascade Impactor instrument utilizes coated quartz crystal microbalances to capture and measure aerosol content of air pumped through sized orifices.

The accelerated particles are acted upon principally by two forces: inertial, which tends to cause impact on the crystal, and aerodynamic viscous drag, which tends to turn the particle along flow streamlines, thus missing the impact plate and proceeding to the next stage. Size discrimination results from the balance attained between these two opposing factors. The nozzles are sized for particle discrimination such that each stage has a 50 percent probability of impact for particles of 5.0, 1.0, and 0.3 μm diameter, respectively.

However, further analysis by one of the authors (Wallace) indicates that for all the IECM flights, the metered airflow may have been too high and the geometrical configuration provides preferential measurements of particles from inside the IECM, especially for particles larger than 10 μm .

These problems originated from a decision to fly the prototype instrument and not develop the flight instrument. This decision was based on funding problems and resulted in not having an instrument available for further testing and development.

The results of the measurements from the SL-1 indicate that there was insufficient particulate mass deposition on the three stages for sensible detection during ascent.

Scanning Electron Microscopy (SEM) photography was performed at relatively low magnification and confirmed lower particle counts than on previous missions. Elemental analysis of several of the particles are given in Table III-1. The elemental analysis does not include carbon, aluminum, or silicon due to high backgrounds and is limited to atomic numbers above 8.

*Celesco Consultants, Huntington Beach, CA.

TABLE III-1. CASCADE IMPACTOR ELEMENTAL PARTICLE ANALYSIS

Element	Mole Fraction				
	Particle #1	Particle #2	Particle #3	Particle #4	Particle #5
Cl	28.78	11.68	9.28	31.03	5.96
Ca	24.04	34.77	45.66	24.48	19.04
K	14.51	11.47	8.07	22.41	7.5
S	7.0	11.13	8.8	11.95	52.12
Ti	6.93	2.82	2.53	-	-
Na/Zn	5.47	6.18	2.19	-	-
Mg	5.41	9.62	12.05	-	13.46
P	4.76	8.86	3.13	4.25	-
Fe	2.17	2.06	4.82	1.15	1.92
Zn	0.93	1.65	3.49	-	-
Na	-	-	-	4.71	-

Particle #6		Particle #7		Particle #8	
Element	Mole Fraction	Element	Mole Fraction	Element	Mole Fraction
Zn	87.79	S	88.03	Au	69.65
S	5.25	Cl	11.97	K	11.28
Fe	2.48			Mg	9.73
Ca	2.39			Fe	5.45
Cr	2.10			Na	3.89

IV. OPTICAL EFFECTS MODULE AND PASSIVE SAMPLE ARRAY

R. C. Linton

A. Optical Effects Module (OEM)

The OEM is an active monitor of monochromatic (253.7 nm) ultraviolet transmittance and scatter, operating during the orbital phase of the mission. Five ultraviolet "witness samples" are mounted on the periphery of a carousel that rotates in the Shuttle X-Z plane. A sixth, empty, sample holder is included for self-calibration of the transmittance measurements during each operational sequence.

A complete OEM sequence includes approximately 8 min of static exposure, followed by a measurement phase lasting 77 sec. In the measurement phase, the samples are sequentially "stepped" through the internal light-beam-detector path by rotation of the carousel. The initial sequence for Spacelab 1 (triggered by the IECM power-on command) was recorded at approximately 0.28 hr MET; the last sequence began at 176.77 hr MET.

Three of the five OEM samples for SL-1 were selected to provide data concerning the interaction of orbital atomic oxygen; Figure IV-1 is a summary of the SL-1 OEM transmittance data results, with a listing of the materials flown and their relative location on the OEM carousel. Sample positions I_1 , I_2 , and I_4 were selected for atomic oxygen sensitive optical materials, while position I_5 , diffuse fused silica, was selected as a standard to reference the scatter channel data. The sample in position I_3 , with direct -Z axis exposure, was dedicated solely to contamination effects monitoring. The uncertainty in these OEM transmittance measurements is about ± 1 percent ΔT , or ± 2 percent $\Delta T/T_0$ (percent change in transmittance). Excluding, for a time, discussion of the anomalous indicated transmittance increase of sample I_2 during the ground-to-orbit phase, the results indicate minimal change due to the induced or natural environment. For the in-orbit phase, the results indicate changes of transmittance within the limits of uncertainty for all samples except I_5 , the diffuse fused silica. No proven explanation is available at this time for the large changes in transmission of I_5 .

Figure IV-2 is a summary of the in-flight recorded transmittance data for the four transmitting OEM samples. The results indicate no significant degradation, within the limits of uncertainty, for any except the I_5 diffuse fused silica sample. These results can be interpreted as indicating no significant accumulation of contamination.

The osmium mirror (I_4) and the carbon coated windows (I_1 and I_2) were expected, upon exposure to the orbital atomic oxygen, to increase in transmittance proportional to the loss of the carbon and the osmium thin film layers. The indicated change for the thin carbon-coated CaF_2 window was small, and within the measurement error limits. There was no indicated change in the opacity of the osmium-coated quartz substrate. Sample I_2 , carbon-coated magnesium fluoride, as indicated in the OEM schematic of Figure IV-1, had much more exposure than Sample I_1 , which only

was rotated to the external environment during the intermittent measurement phases. Sample I₂ increased from approximately 4 percent transmittance pre-launch to approximately 6 percent transmittance on-orbit; whether this increase is due to atomic oxygen interaction or to some other instrumental measurement factor is still being investigated.

Scatter channel data from the OEM for Spacelab 1 are more difficult to interpret due to the unforeseen changes in the diffuse "standard" sample. However, post-flight analyses of the particulate distributions on the OEM samples, and a preliminary review of the scatter channel data, indicate minimal particulate accumulation, Level 300-500. Figure IV-3 shows the scatter channel readings during the SL-1 mission for Sample I₃; increased diffuse reflection, or scatter, from the samples would be indicated as an increase in the scatter channel readings, when corrected for instrumental variations.

The OEM housing temperature profile for the flight is given in Figure IV-4.

B. Passive Sample Array (PSA)

The PSA contains a number of optical materials exposed as "witness samples." The PSA is mounted on the top (-Z) surface of the IECM, in the Shuttle X-Y plane. Like the OEM the PSA has no protective covers in place during ascent, orbit, descent, or ferry-flight.

For the ferry-flight phase of the mission, a Passive Optical Sample Assembly (POSA) unit of additional "witness samples" was mounted in the Shuttle payload bay (X \approx 750), postflight, at the Dryden Flight Research Facility. The POSA ferry-flight unit provides a means of estimating the contributions of the ferry-flight environment on the condition of samples exposed through the entire mission.

The PSA for SL-1 contained 45 optical samples, one KRS-5 crystal, and three "electrets" [1]. One of the eight PSA trays, containing the KRS-5 crystal, was supplied as guest experimenter hardware [2]; no results for these guest samples are presented in this report.

Optical reflectance and transmission measurements of flight samples from the Passive Array appear to provide conflicting information on contamination effects. Measurements were conducted over a wavelength range from 120 to 2500 nanometers. Aluminum mirrors overcoated with magnesium fluoride were not degraded; there is evidence of some improvements in reflecting efficiency in the vacuum ultraviolet (Figs. IV-5 and IV-6). Gold mirrors (\sim 600 Å) provide evidence of a significant degrading effect in the vacuum ultraviolet (50 percent decrease at 121.6 nanometers), while small changes are seen in BK-7 type glass (Fig. IV-7 and IV-8).

Transmissive samples, including those of the type mounted in the OEM, show no significant change or evidence of contamination. Platinum mirrors show no significant change; the measured changes on other types of samples either indicate no contamination effects or effects possibly due to other influences of natural environment origin (e.g., atomic oxygen). Samples from the ferry-flight POSA unit indicate no significant change in optical properties.

There is some evidence of a detectable contamination on the PSA gold mirrors from Auger spectroscopic investigations (J. Swann, U. of Ala.); evidence of a similar contaminant was found on the OEM osmium mirrors. These Auger results are not

conclusive evidence of contaminant deposition. Further investigation of a similar nature is planned to verify and identify contaminants on these flight samples.

For a measurement of the effects of contamination caused by the Shuttle ground operating environment for SL-1, trays of optical samples were exposed and exchanged in the O&C and the OPF at KSC during the IECM/pallet exposure phases in these facilities.

Optical reflectance and transmittance measurements over the wavelength range of 120 to 2500 nanometers do not show any evidence of molecular film contamination on samples exposed in these facilities.

The particle count distributions on exposed PSA witness samples were measured on the MSFC automated Omnicron imaging facility (W. V. Witherow, ES74). Results averaged for particles counted on both reflecting and transmissive optics are summarized in Table IV-1, for all mission phases, including ground-handling. The particle size distributions, as measured, are provided for comparison in Figure IV-9, indicating the differences as measured for samples exposed to the pre-flight, flight, and ferry-flight environments.

TABLE IV-1. IECM-SPACELAB 1 PARTICULATE CONTAMINATION
PASSIVE SAMPLE ARRAY

I. Ground-Handling Environment

A. MSFC→KSC (O&C Building), August 1982-April 28, 1983

$$\text{Number Particles/cm}^2 = 8.1 \times 10^2$$

B. KSC: O&C to First Access O.P.F., April 28, 1983 to
August 19, 1983

$$\text{Number Particles/cm}^2 = 2.0 \times 10^3$$

C. KSC: O.P.F. to IECM Close-out, August 19, 1983 to
September 14, 1983

$$\text{Number Particles/cm}^2 = 2.6 \times 10^3$$

II. Ferry-Flight SL-1 (Location $X_o = 750$)

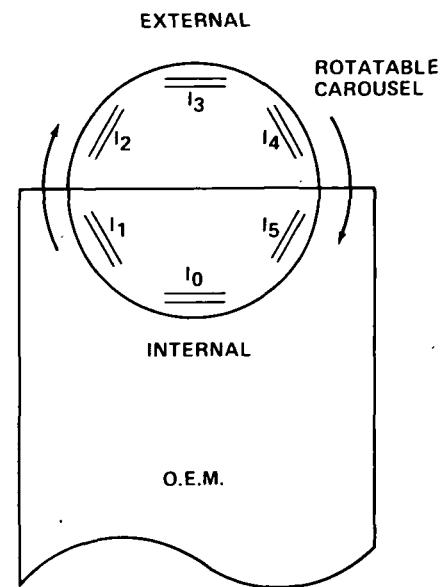
$$\text{Number Particles/cm}^2 = 8.5 \times 10^2$$

III. Flight (Including Ferry Flight) (Location $X_o = 1287$)

$$\text{Number Particles/cm}^2 = 7.2 \times 10^2$$

SAMPLE LISTING:

POSITION	MATERIAL
I ₀	OPEN APERTURE
I ₁	CALCIUM FLUORIDE WITH 50Å CARBON
I ₂	MAGNESIUM FLUORIDE WITH 200Å CARBON
I ₃	MAGNESIUM FLUORIDE
I ₄	OSMIUM ON QUARTZ
I ₅	DIFFUSE QUARTZ, TRANSLUCENT



MEASURED CHANGE IN TRANSMITTANCE
(2537 ANGSTROMS)

MISSION PHASE	I ₁	I ₂	I ₃	I ₄	I ₅
PRE-FLIGHT GROUND-OPS	0	0	0	*	-9%
GROUND TO ORBIT	+1.7%	+40%	-1.1%	*	-10%
IN-FLIGHT	+1.6%	0	-1.1%	*	-42%
POST-LANDING (INCLUDING FERRY FLIGHT)	-1.6%	0	0	*	-27%
TOTAL CHANGE	+1.7	+40%	-2.2%	*	-65%

* OPAQUE

Figure IV-1. Optical effects module summary results: Spacelab 1.

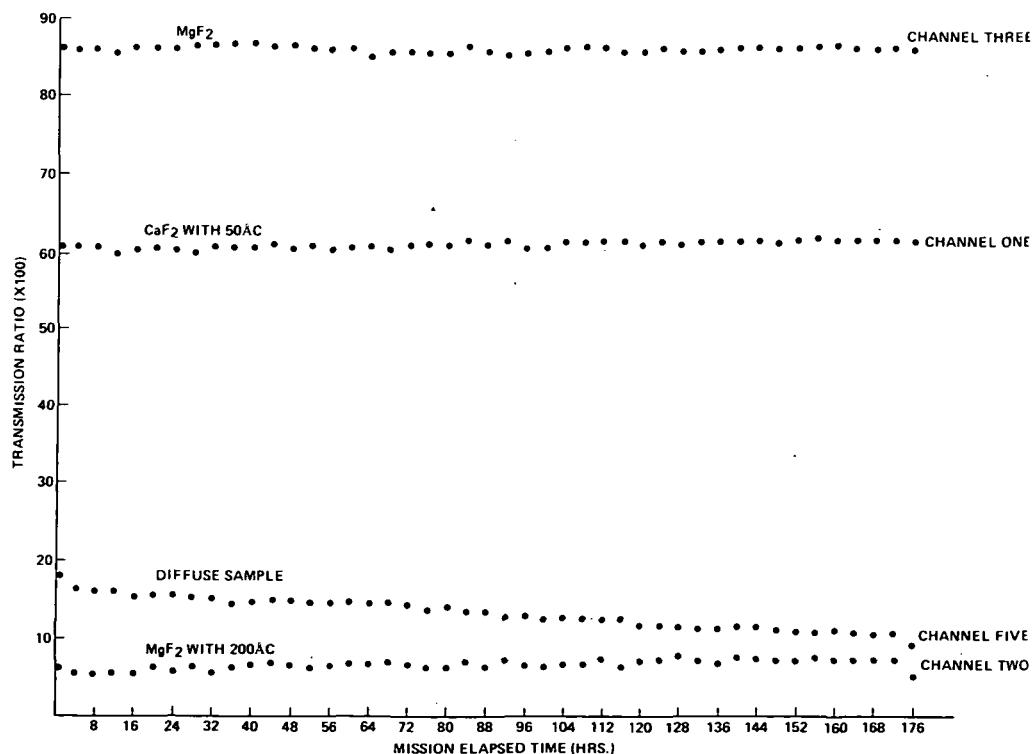


Figure IV-2. OEM results - Spacelab 1.

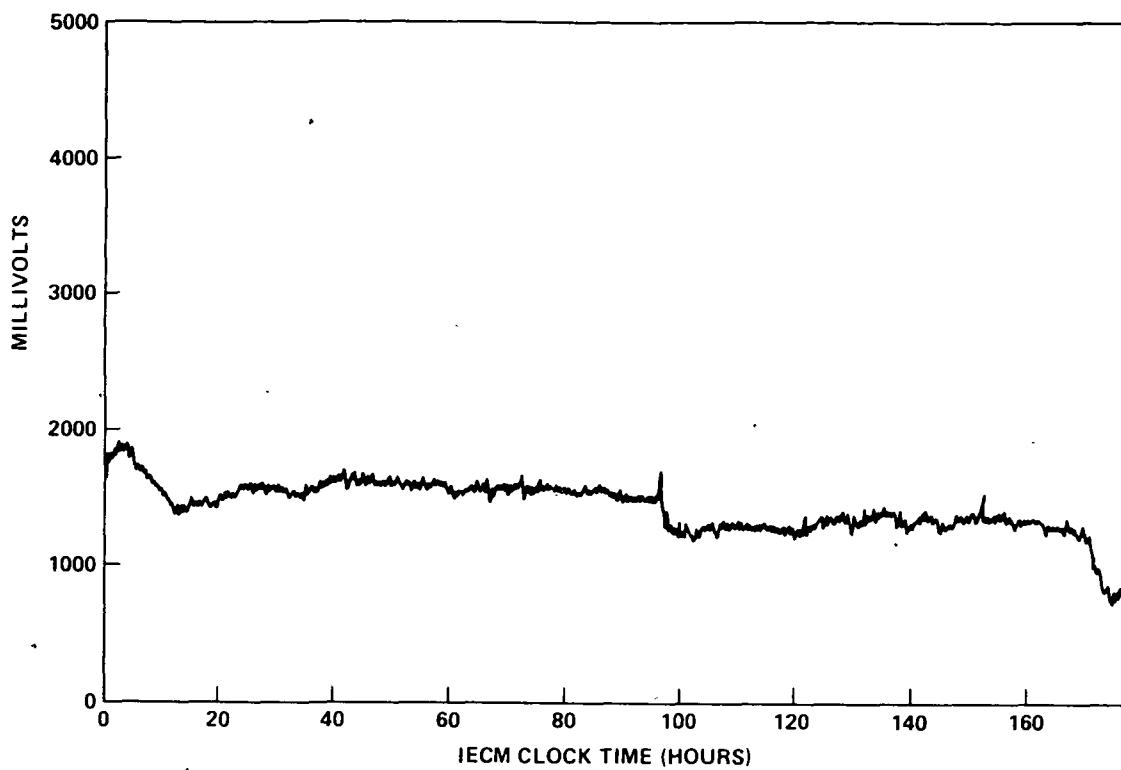


Figure IV-3. OEM-Spacelab 1 diffuse reflection signal channel $I_3\text{-MgF}_2$.

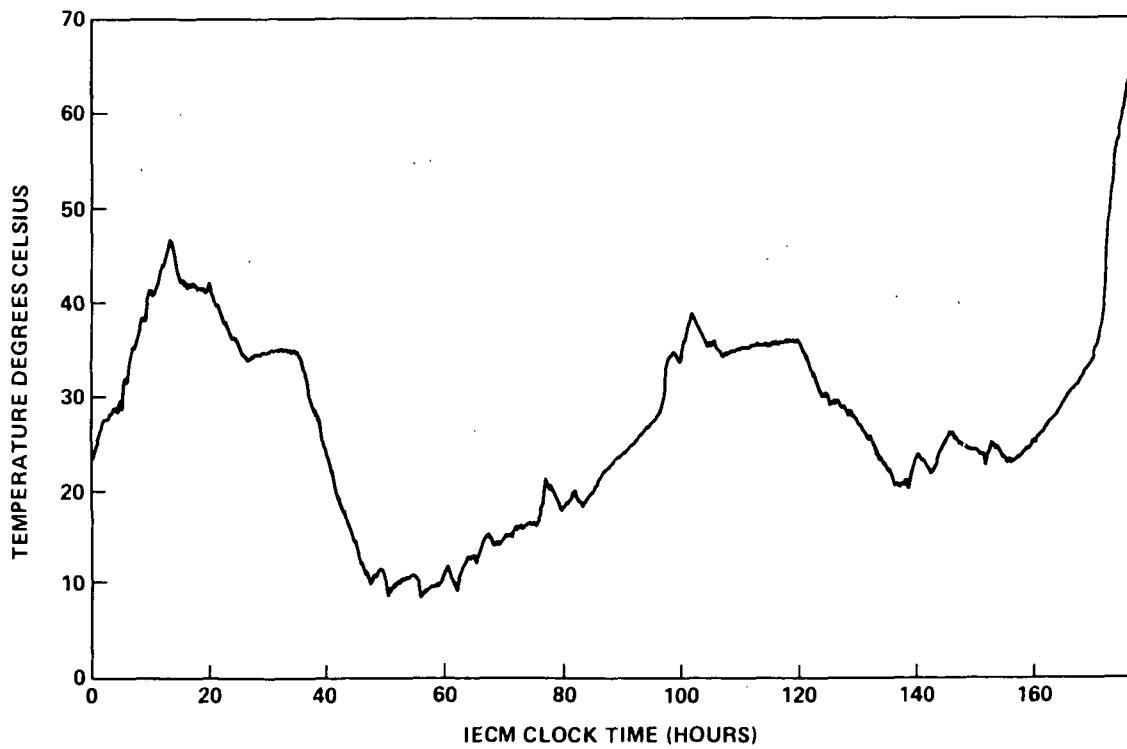


Figure IV-4. Housing temperature OEM-Spacelab 1.

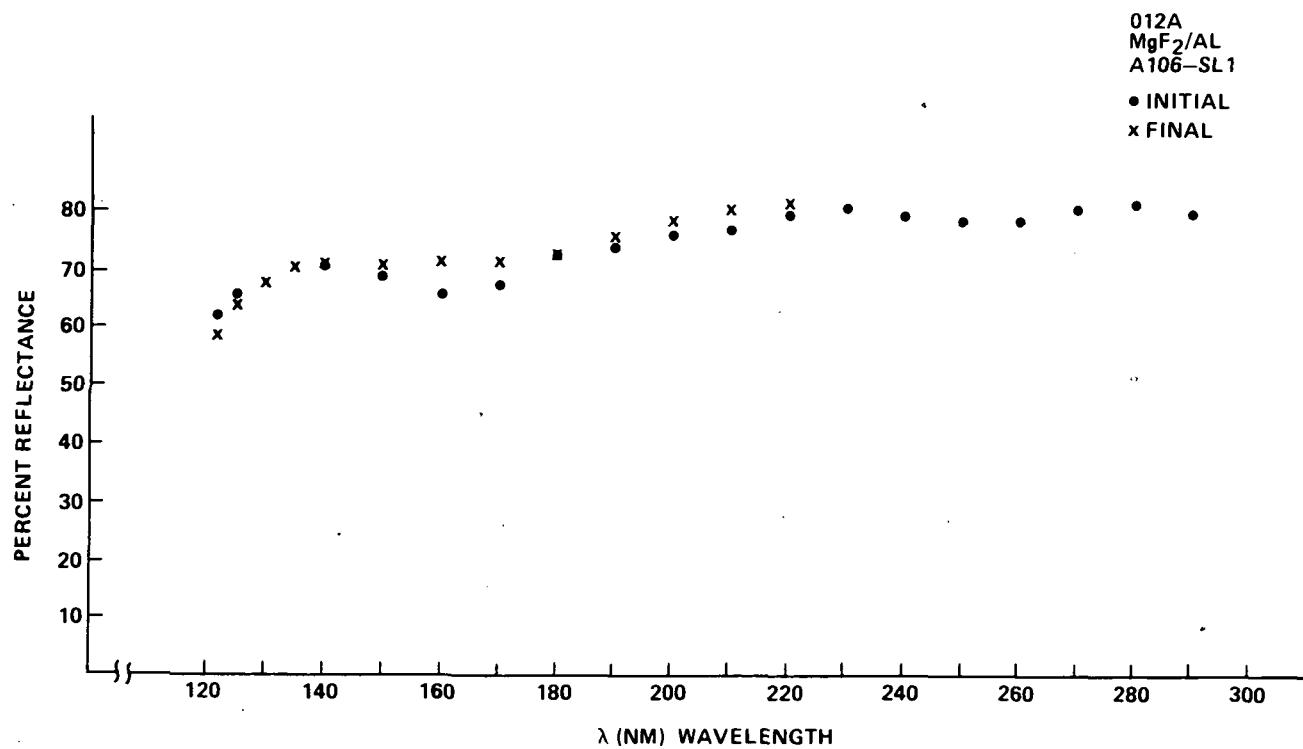


Figure IV-5. PSA SL-1 pre- and post-flight reflectance.

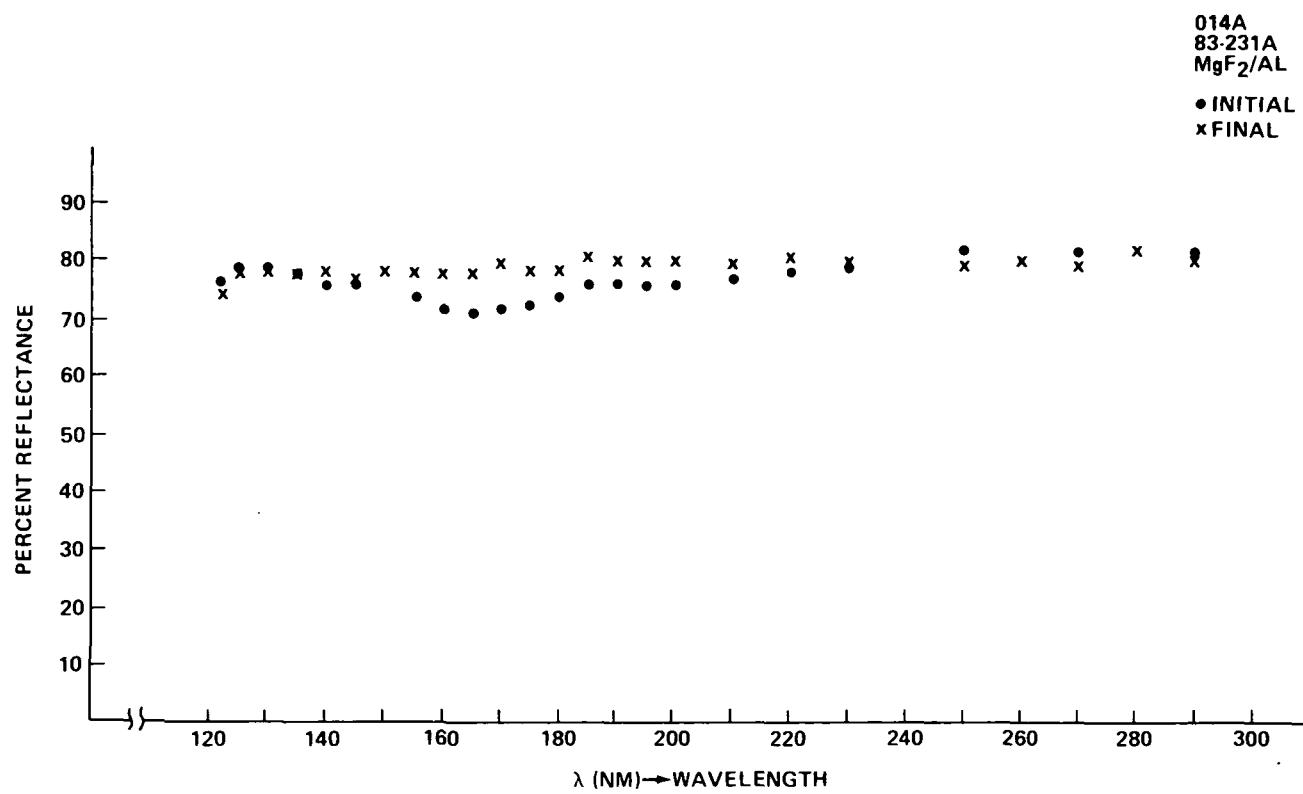


Figure IV-6. PSA SL-1 pre- and post-flight reflectance.

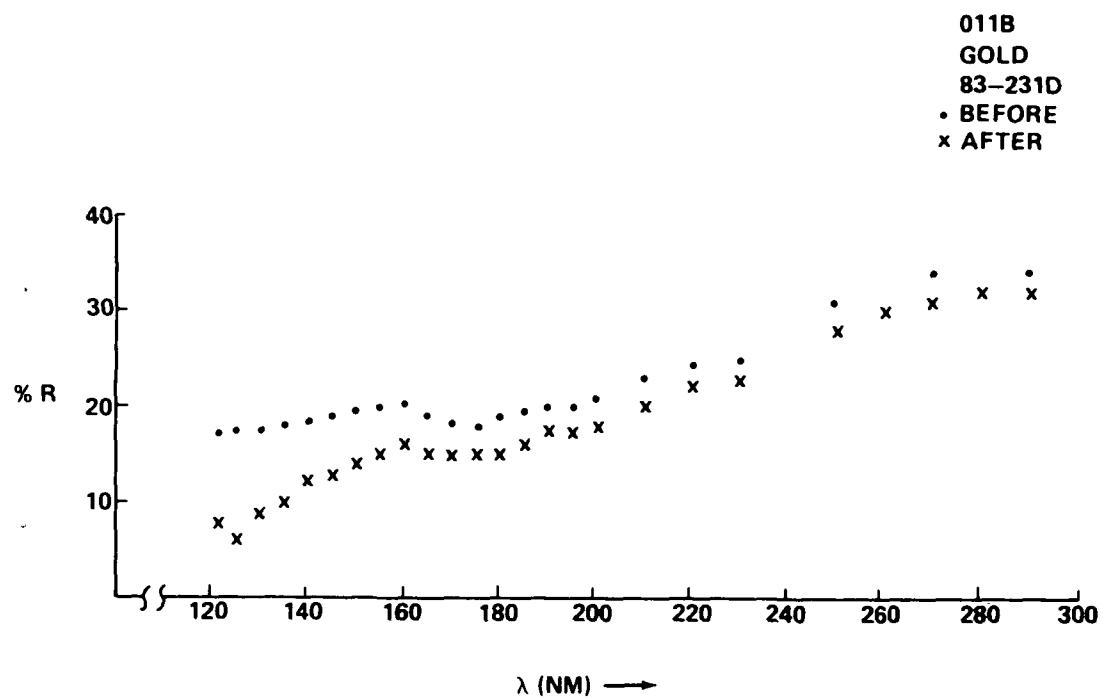


Figure IV-7. PSA SL-1 pre- and post-flight reflectance.

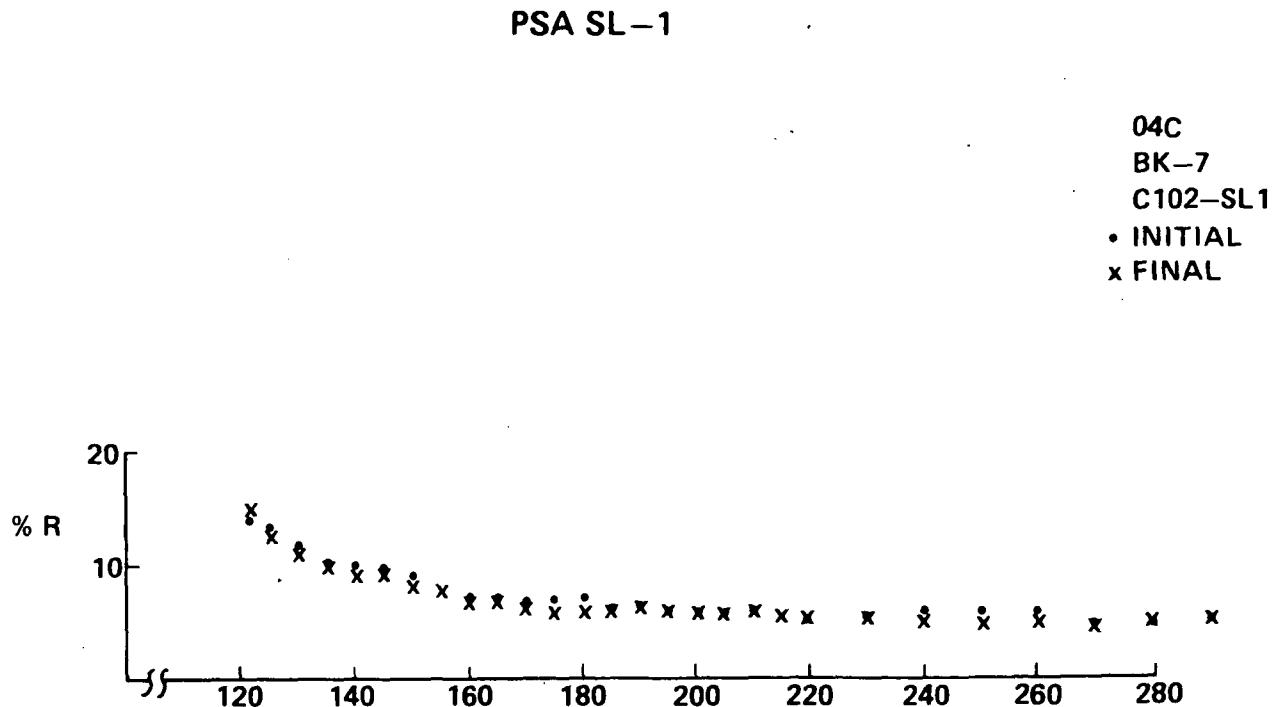


Figure IV-8. PSA SL-1 pre- and post-flight reflectance.

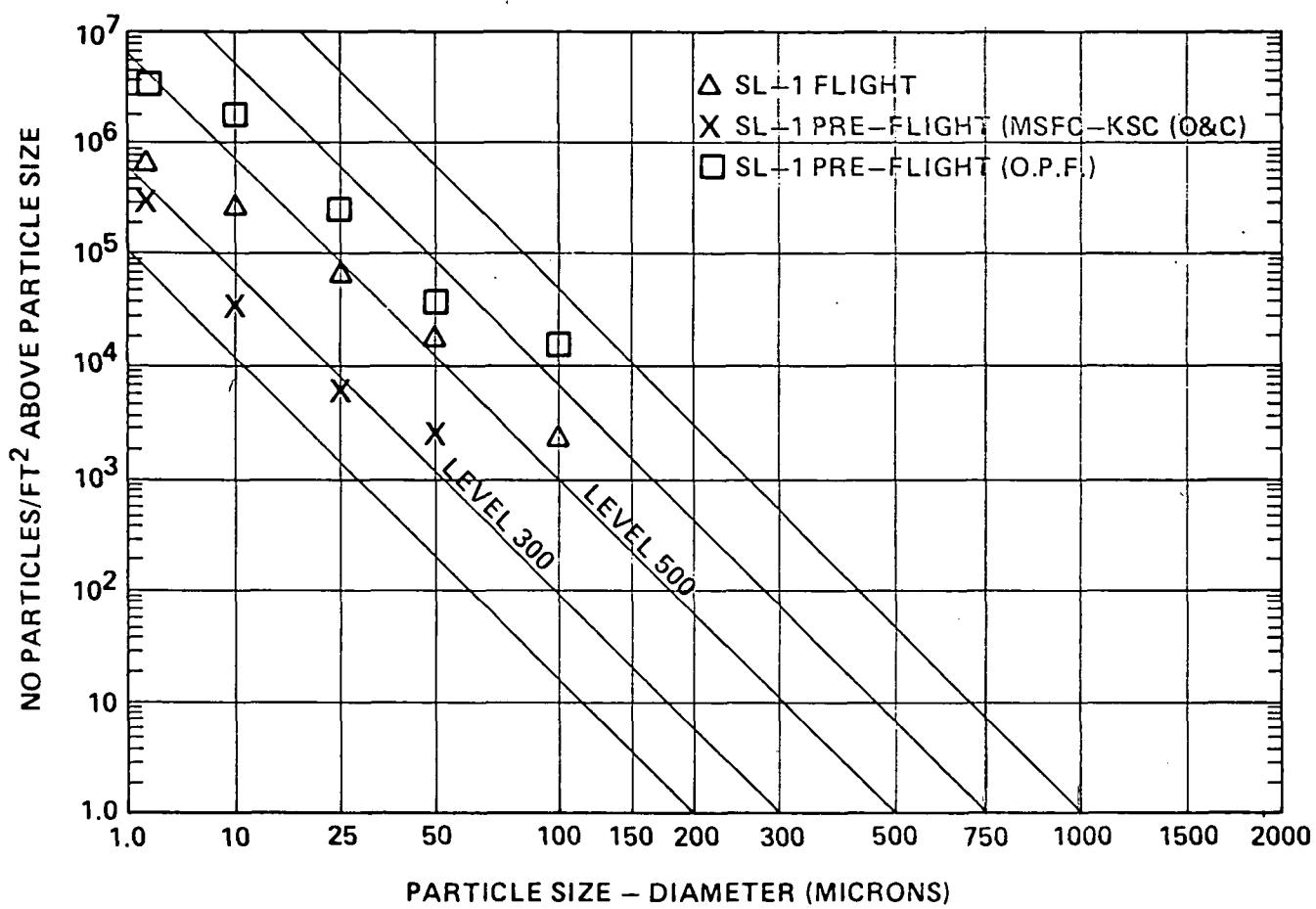


Figure IV-9. Product cleanliness levels from MIL-STD-1246A.

V. QUARTZ CRYSTAL MICROBALANCE SURFACE CONTAMINATION MEASUREMENTS

By J. A. Fountain and D. McKeown*

INTRODUCTION

The Temperature-Controlled Quartz Crystal Microbalance (TQCM) and the Cryogenic Quartz Crystal Microbalance (CQCM) were flown as a part of the Induced Environment Contamination Monitor (IECM) to measure surface contamination in the payload bay of the Spacelab 1 (STS-9) mission. The TQCM and CQCM systems [1] have been flown on three previous Space Shuttle flights [2-5]. The system can detect 1.56 ng/cm^2 of Volatile Condensable Material (VCM) absorbed or desorbed from a surface.

The TQCM has active temperature control and can be commanded to operate at temperatures between -60 and $+80^\circ\text{C}$. It measures low-volatile contaminants, such as, lubricants and epoxies. Its five sensors point along the Orbiter axes: $+Y$ (right), $-Y$ (left), $+X$ (fore), $-X$ (aft) and $-Z$ (vertical).

The CQCM is not temperature controlled and uses a radiator to cool its sensors to temperatures below -100°C when pointed into deep space. Its main purpose is to measure high-volatile contaminants, such as, water vapor and CO_2 . Its two sensors were pointed along the $-Z$ axis to view space.

The amount of contamination measured on STS-9 was significantly greater than on missions STS-2, 3, and 4. On previous missions, the payload bay was relatively empty, while on STS-9 the bay included not only the Spacelab module, but also a pallet loaded with instruments in close proximity to the IECM. As a result, the contamination measured on STS-9 attained extremely high-levels of $28,000 \text{ ng/cm}^2$, over 1700 percent greater than measured on previous flights.

On STS-2, 3 and 4, the TQCM was periodically commanded to temperatures between -60 and $+80^\circ\text{C}$ to measure contamination adsorption and desorption rates as a function of temperature. The TQCM sensors on STS-9 were commanded to 0°C at lift-off to measure contamination build-up at a constant temperature. The TQCM remained in this mode until the IECM ceased operation at 177 hours MET.

THE DATA

In the data discussed in this section, orbiter attitude timeline information is from the "STS-9 FAO/CAP Post Flight Report" (Crew Activity Plan) [5] and orbiter axis pointing information and other pertinent data such as the position of the sun and the sunlight/shadow data was provided by the Orbital Mechanics Branch of the Systems Analysis and Integration Laboratory of MSFC.

Figure V-1 shows plots of mass deposition in nanograms per square centimeter on the TQCM sensors as a function of Mission Elapsed Time (MET) in hours up to 177 hours MET. The Payload Bay doors opened at 1h 25m MET and from that time

*Staff Scientist, Faraday Laboratories Inc.

there was an increase in molecular deposition on all of the side pointing sensors, and relatively little deposition on the -Z sensor, which points out of the Payload Bay. At 13h MET, began a period of small increases in adsorption or even desorption until the Orbiter turned Bay-to-Sun for Experiment 1ES816 at 96h 18m MET. This hot position produced much outgassing of instruments in the Payload Bay and is seen dramatically on the +X, or forward pointing sensor. After this time the +X sensor continued to collect contamination while the other side pointing sensors gave up mass until the Hot Case Test was begun at 170h 25m MET. At that time all sensors recorded large amounts of contamination, with the +X adsorbing the most. At the end of the measurements, the +X sensor has reached $28,000 \text{ ng/cm}^2$. This is a factor of about 18 higher than the highest amount of contamination recorded during the previous three flights. (That was during the Hot Case Test of STS-3). It is also noted that the contamination that adsorbed on the +X sensor remained on the sensor, while the contamination that adsorbed on the other side viewing sensors, up until the beginning of the Hot Case, desorbed. For the -X and -Y sensors, the contamination level fell below the level at the beginning of the mission. The -Z axis sensor showed a relatively small amount of collection over the entire mission, but its rate was steady and for the most part, unaffected by Orbiter attitude changes that so drastically affected the other sensors.

Figures V-2, -3, and -4 show in detail the three portions of the flight that recorded the most contamination. Figure V-2 shows the time between lift-off and 16h 40m MET. After a quiescent time when the payload bay doors were closed, the contamination begins to collect at 1h 25m MET in the Bay-to-Earth attitude, even on the -Z axis. When the Orbiter turns to the IMU alignment attitude, which is a Bay-to-starfield attitude, the -Z axis desorbs its contamination mass and remains clean for the rest of the period. On the other hand, the other sensors start adsorbing contamination when the Orbiter is in a -XLV (Tail-to-Earth) attitude, and this trend continues until the movement to acquire the Tracking Data Relay Satellite (TDRS) at 13H MET. The -Y, +Y, and +X axes collected between 4300 and 5200 ng/cm^2 during this period, and the -X sensor collected 1200 ng/cm^2 . This large increase in contamination is caused by solar heating of the Bay. The sun throughout this period was approximately 45 degrees from the -Z axis. The effects of the sunlight/shadow exposure results in large rates of adsorption during the sunlit portion of the orbit and low rates when the Orbiter is in the Earth's shadow (see for example the +Y axis sensor in the period between 6 h 56m and 8h 24m MET).

Figure V-3 shows a nine hour period during which the Orbiter turns very quickly from a period of no sunlight on the Payload Bay to Full sun. For this graph, the sensor output curves are normalized to zero at the quiescent period of -ZLV (Bay-to-Earth) at 95H MET. The most significant information depicted here is not only the increase of over 3900 and 700 ng/cm^2 for the +X and +Y axis sensors, respectively, but the fact that after the relatively short period of direct sunlight is long over, at 104h MET, 71 percent of the contamination adsorbed remains on the sensors. This indicates polymerization by UV has occurred permanently fixing the contamination to the surface. Also note that the -Y axis sensor, which collected the most contamination on Figure V-2, was not dramatically affected in this period. The -X and -Z axis sensors showed little effect at all.

At 170h 25m MET, the Orbiter began the Hot Test by turning the -Z axis into the Sun. This Test lasted for seven hours, but the IECM ceased operation at 177h MET. Figure V-4 shows this time period, and for comparison, more than two hours before the Hot Test started. This Hot Test was different from the previous flights

in that the orbital inclination angle was changed so that the Orbiter was almost in full sun, that is, the time in the Earth's shadow was just a few minutes per orbit. These severe conditions resulted in surface temperatures of $>80^{\circ}\text{C}$. The effects of component outgassing in the bay are seen in Figure V-4. In this figure, as in Figure V-3, the sensor output values are normalized to zero at the period just prior to the Hot Case, so the values shown are relative only to the Hot Case Test, not the entire mission. During this test, the $+X$ axis sensor recorded $28,000 \text{ ng/cm}^2$, the $-Y$ $17,000 \text{ ng/cm}^2$, and the $+Y$ increased by $8,600 \text{ ng/cm}^2$. The $-X$ axis sensor, which is directed at the aft Bulkhead, recorded $2,650 \text{ ng/cm}^2$, which is in good agreement with its value for the Hot Case Test on STS-3. It is the only sensor (other than $-Z$) which has essentially the same "measurement view" as the previous flights. At 174h 25m MET, the temperature control circuit of the $-Z$ axis ceased operation, so the $-Z$ data terminates at that time.

Figure V-5 shows that CQCM sensor output plot for the $-Z_1$ sensor and its temperature from lift-off to 177h MET. The CQCM measurements are shown on the same scale as the TQCM (Fig. V-1) in order to show the similarity between the $-Z$ axis measurements by the two systems. The output from the $-Z_2$ sensor is not shown because it coincides so closely with the $-Z_1$ plot. The CQCM sensor temperature measurements ranged from $+37^{\circ}\text{C}$ to -83°C . The actual temperatures went above $+37^{\circ}\text{C}$ in the first few hours and during the Hot Test, but this is the maximum temperature value that the CQCM can measure. The minimum value of -83°C was reached by the $-Z_1$ sensor during the Cold Test from 35h 21m to 58h 46m MET. The CQCM temperatures for the most part stayed generally between $+10^{\circ}\text{C}$ and -40°C . Contamination deposition as measured by the CQCM on the $-Z$ axis is less than $4 \text{ ng cm}^{-2} \text{ hr}^{-1}$.

Tables V-1 through V-5 give values of contamination deposition rates on a per hour basis for comparison with data given in the references for the previous flights.

CONCLUSIONS

Molecular contamination, as recorded by the TQCM sensors which have fields-of-view which include instruments in close proximity, is significant when compared to measurements taken on STS-2, 3, and 4. The aft viewing $-X$ axis sensor, which views the aft bulkhead, measured values during the Hot Case Test which were in good agreement with values under similar conditions of STS-3. The $-Z$ axis sensor of the TQCM and the $-Z_1$ and $-Z_2$ sensors of the CQCM, were in good agreement in showing relatively little contamination arriving from the $-Z$ direction. General conclusions are (1) that molecular contamination as a result of outgassing and offgassing of components, is significant, especially when there is solar heating of the bay either directly or by angles of 45 degrees from the $-Z$ axis; and (2) contamination by redirection of outgoing molecules by ambient atmospheric molecules is small in the $-Z$ axis.

TABLE V-1. ADSORPTION PER HOUR FOR THE ORBITAL PHASE - TQCM.
 [See Fig. 1 (time period is from effective collection beginning
 time* to 177h MET)].

AXIS	MASS PER UNIT AREA nanograms/cm ²	TIME PERIOD hours	CONTAMINATION RATE nanograms/cm ² /hr
-Z	1,407	171.37	8.2
+Y	6,304	175.53	35.9
-Y	11,046	175.53	62.9
+X	27,927	175.90	158.8
-X	1,605	175.37	9.2

*Time at which sensor cleans to a minimum frequency during the first few hours of the mission and begins collecting mass. It is different for each sensor.

TABLE V-2. ADSORPTION PER HOUR DURING THE -XLV, YVV
 ATTITUDE FROM 03h 14m TO 12h 50m MET (see Fig. 2)

AXIS	MASS PER UNIT AREA nanograms/cm ²	TIME PERIOD hours	CONTAMINATION RATE nanograms/cm ² /hr
-Z	159	9.68	16.4
+Y	4,359	9.68	450
-Y	4,975	9.68	514
+X	3,708	9.68	383
-X	1,363	9.68	141

TABLE V-3. ADSORPTION PER HOUR DURING THE EXPERIMENT 1ES816
 [Measured from Minimum to Maximum (See Fig. 3)]

AXIS	MASS PER UNIT AREA nanograms/cm ²	TIME PERIOD hours	CONTAMINATION RATE nanograms/cm ² /hr
-Z	-	-	-
+Y	777	0.65	1,195
-Y	250	0.77	325
+X	3,994	1.15	2,226
-X	72	0.95	76

TABLE V-4. ADSORPTION PER HOUR FOR HOT TEST
(170 h to 177h MET, See Fig. 4)

AXIS	MASS PER UNIT AREA nanograms/cm ²	TIME PERIOD hours	CONTAMINATION RATE nanograms/cm ² /hr
-Z	-	-	-
+Y	5,519	6.6	836
-Y	10,914	6.6	1,654
+X	17,951	6.6	2,720
-X	1,683	6.6	255

TABLE V-5. ADSORPTION PER DURING ORBITAL PHASE - CQCM -
[Measured from Effective Collection Beginning Time* to
17h MET (See Fig. 5)]

AXIS	MASS PER UNIT AREA nanograms/cm ²	TIME PERIOD hours	CONTAMINATION RATE nanograms/cm ² /hr
-Z1	604	171.57	3.5
-Z2	363	171.9	2.1

*Time at which sensor cleans to minimum frequency during first few hours of mission and begins collecting mass. It is different for each sensor.

REFERENCES

1. McKeown, D. and Claysmith, C. R.: Quartz Crystal Microbalance Systems for Shuttle Contamination Measurements. AFML-TR-78-190, NASA CP-2039, March 1978.
2. Miller, Edgar R. and Decher, Rudolf (Editors): An Induced Environment Contamination Monitor for the Space Shuttle. NASA TM-78193, August 1978.
3. Miller, Edgar R. (Editor): STS-2 Induced Environment Contamination Monitor (IECM) - Quick-Look Report. NASA TM-82457, January 1982.
4. Miller, E. R. and Fountain, J. A. (Editors): STS-3 Induced Environment Contamination Monitor (IECM) - Quick-Look Report. NASA TM-82489, June 1982.
5. Miller, E. R. (Editor): STS-2, -3, -4 Induced Environment Contamination Monitor (IECM) Summary Report. NASA TM-82524, February 1983.
6. Numte, Robert H., Memorandum DH4-83-438, STS-9 FAO/CAP Post Flight Report, January 5, 1983.

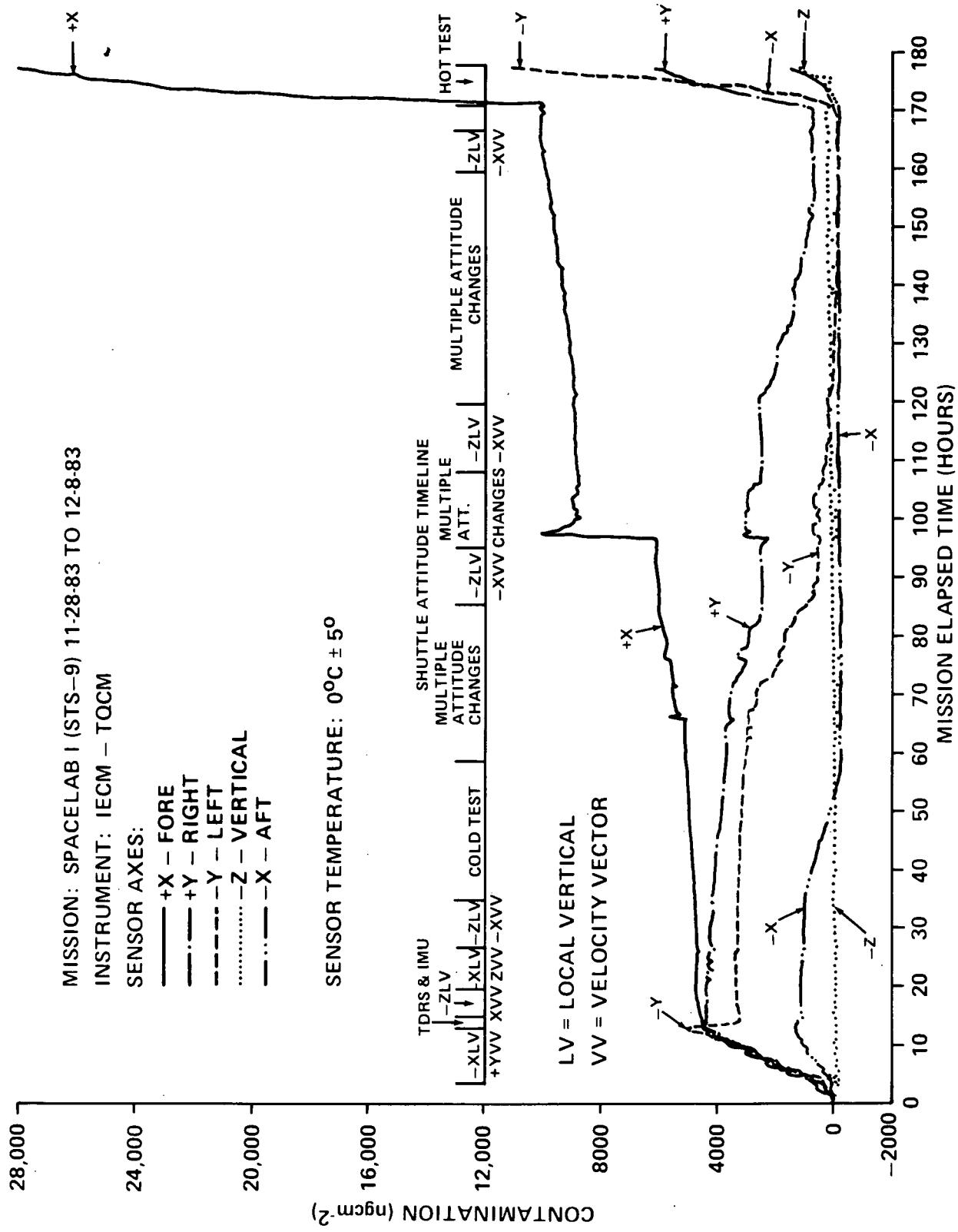


Figure V-1. Surface contamination as measured by TQCM on Spacelab 1.

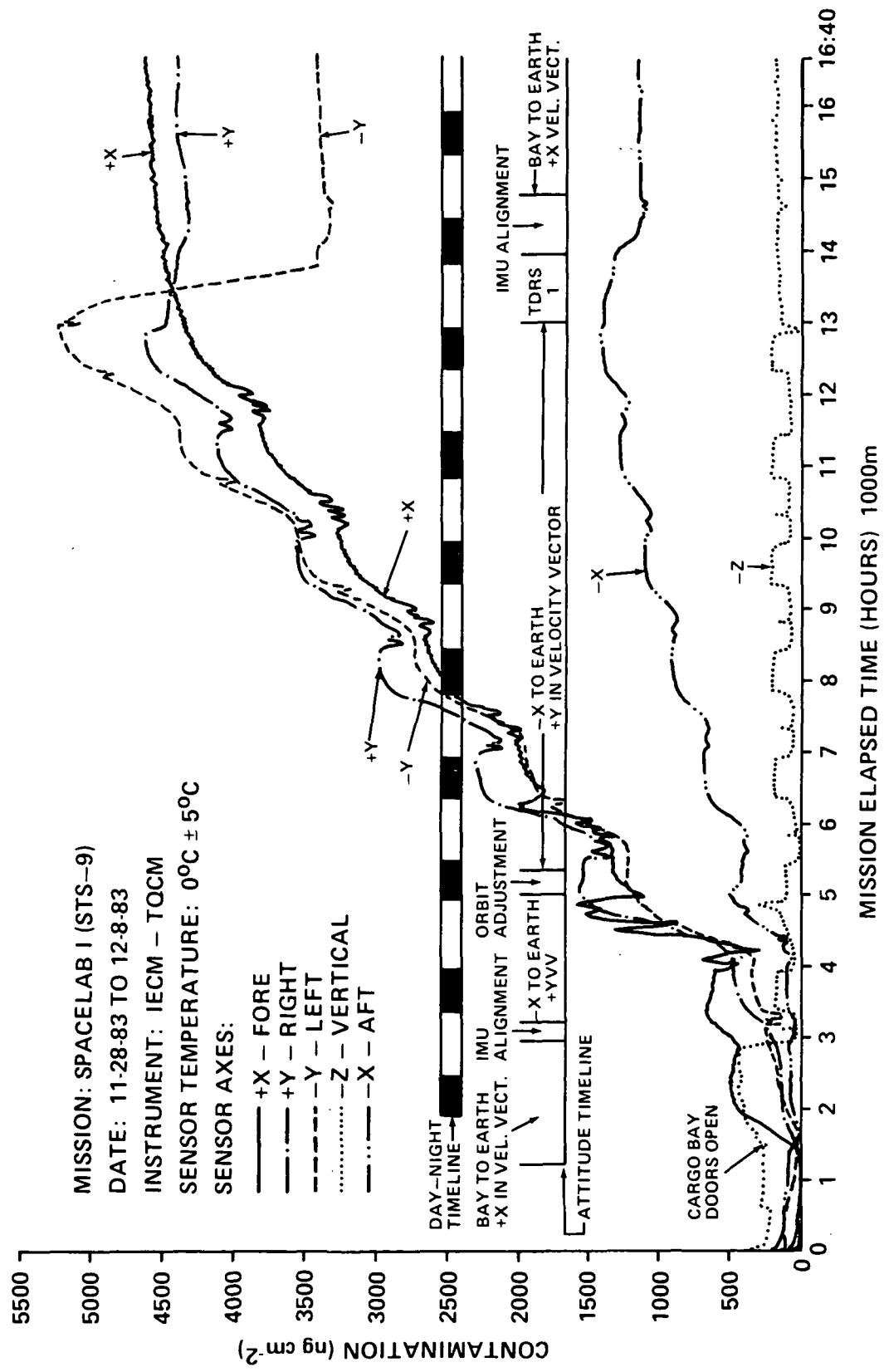


Figure V-2. Surface contamination on Spacelab 1, first 16.7 hours.

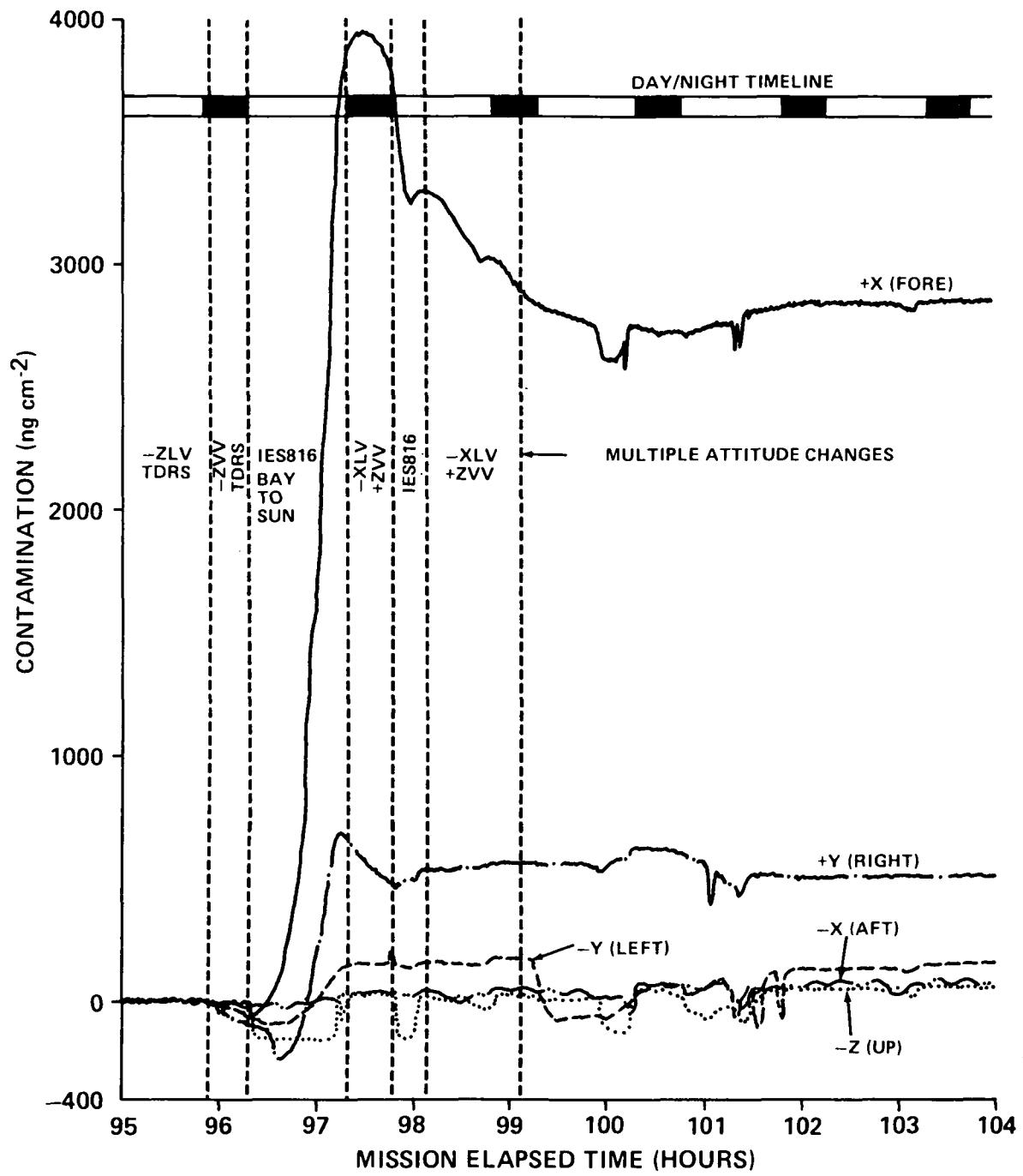


Figure V-3. Surface contamination during solar oriented experiment.

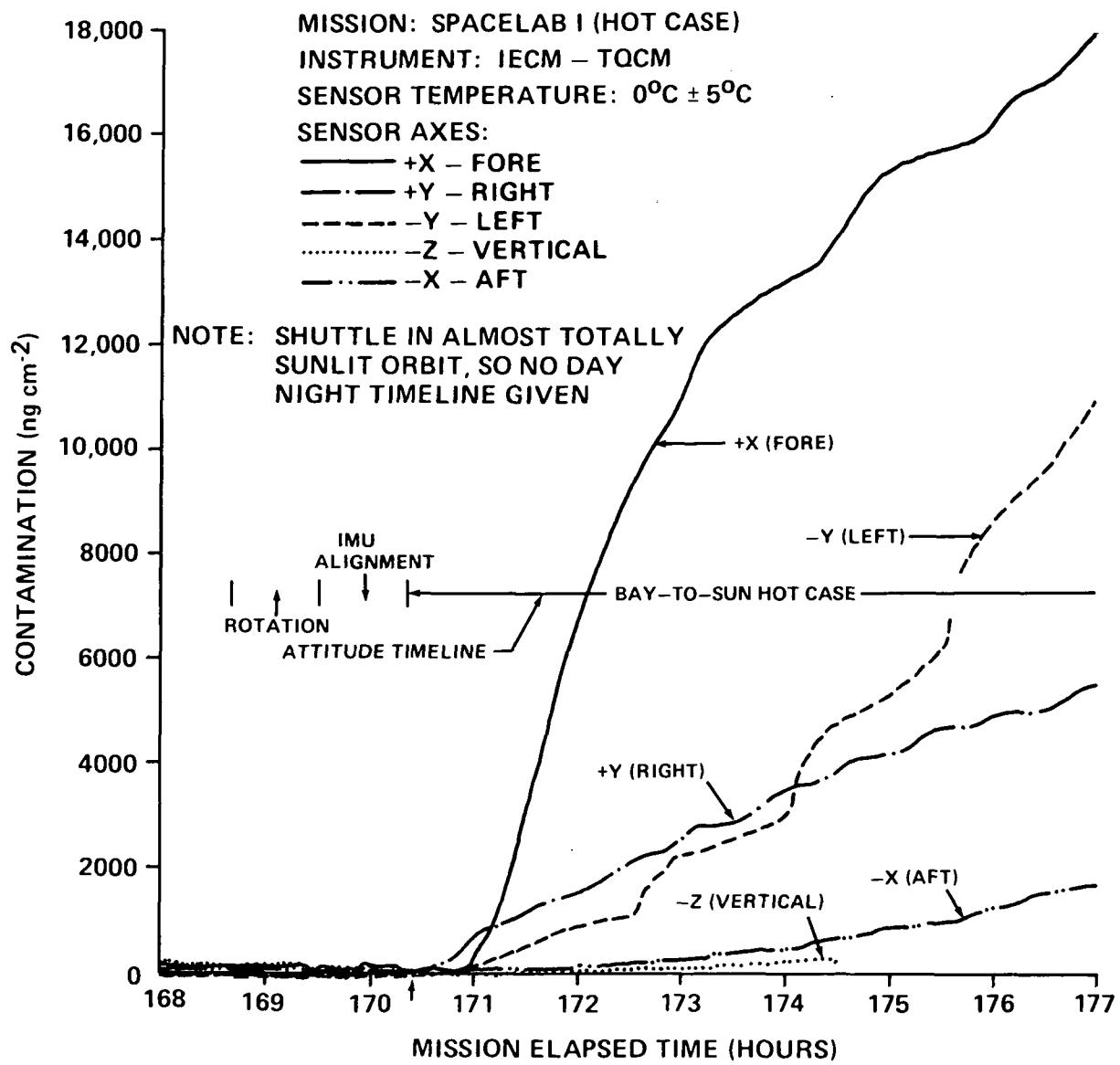


Figure V-4. Surface contamination during bay-to-sun hot case.

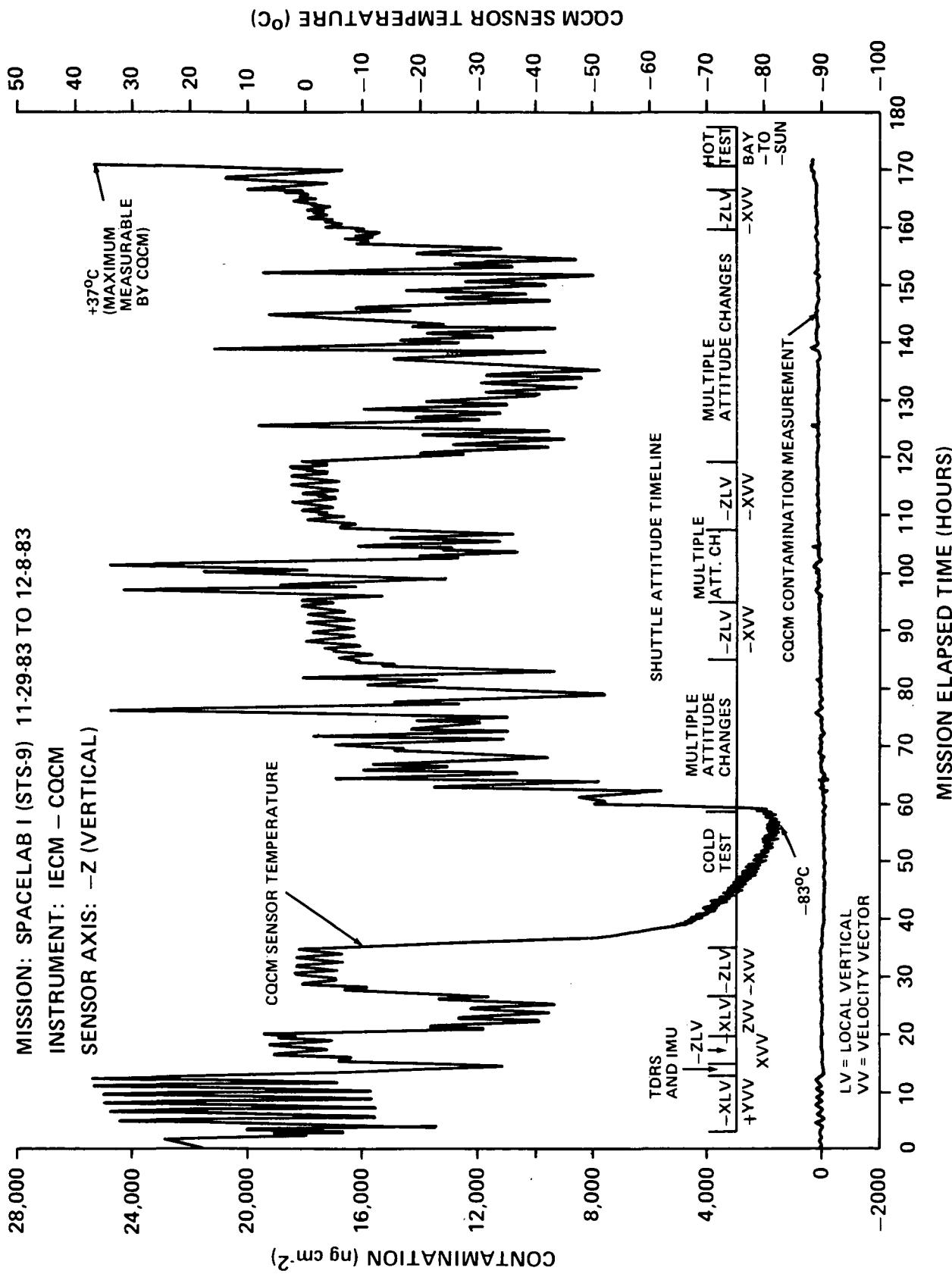


Figure V-5. CQQCM surface contamination measurements and sensor temperature.

VI. CAMERA/PHOTOMETER

By J. K. Owens and K. S. Clifton

Measurements of optical contamination were undertaken by two Camera/Photometers flown as part of the Induced Environment Contamination Monitor (IECM) on board STS-9. The objectives of this experiment were to record the size and velocity distributions of STS-induced particulates and to measure the background brightness resulting from unresolved contaminants. As during the Orbital Flight Test (OFT) mission, two cameras were utilized to make stereoscopic observations of contamination continuously during the on-orbit phase of the Spacelab 1 mission. Simultaneous exposures were made every 150 sec with exposure durations determined from the level of background illumination recorded by integrating photometers. The cameras were equipped with 18-mm f/0.9 lenses which subtended overlapping 32° fields-of-view. The data were recorded onto Kodak Type 7222 Double X negative film.

Operation of the cameras commenced with acquisition of power to the IECM at a mission elapsed time (MET) of approximately 0h 17m. The cameras operated continuously until 151h MET at which time the film storage capacity of the cameras was depleted. During operation over 3600 exposures were obtained by each camera. Of these 1100 were obtained under conditions suitable for recording contaminant particles. Such conditions require a sunlit environment with a relatively dark background. These conditions are met (1) during daytime operations when the payload bay -Z axis is directed to a stellar background at large solar and terrestrial co-elevation angles, and (2) during periods in which the Orbiter was between the terrestrial terminator and spacecraft sunrise/sunset when the -Z axis was directed towards the dark Earth. A preliminary view of the data indicates that half of the data frames capable of recording contamination showed particle tracks. A breakdown of the data is portrayed in Table 1, in which observed particle concentrations are arranged into categories indicating heavy (>10 tracks), moderate (2-9 tracks), and light (1 track) concentrations per frame.

The high percentage of frames indicating heavy particle concentrations includes data obtained during water dumps and during early mission operation when contamination levels are high. These are periods which are normally avoided by optical science experiments. Figure VI-1 portrays the data arranged with mission elapsed time taken in 5-hr segments. The contamination data are shown as a percentage of potential contamination frames and reflect both the total number of contamination frames and those showing fewer than 10 particles. The latter data is more indicative of the general background as a function of time. The general trend of the STS-9 data is similar to that observed during the OFT mission, with high concentration seen during the first 13 hours tapering off to a quiescent rate later in the mission. A high peak observed during 92-97 hours MET may be statistical in nature, since it is based on so few data frames. The peak observed during 62-67 hours MET, however, is based on a much larger statistical sample and does not seem to be correlated with water dumps or any known major contamination producing events.

The size of the observed particles is greater than or equal to 28 microns. This limiting size is slightly greater than on the OFT missions due to fogging of the film, which resulted from the higher than normal temperatures during the hot case. The data from the temperature monitor indicates a maximum temperature at the film magazine of about 144°F. The film is estimated to have been at a temperature of 100°F or more for about 9 hours. The resulting change in the slope of the characteristic curve for the film and its estimated change in detective quantum efficiency

yield a percent change in detectable particle radius of $\Delta a/a = 14$ percent. This is being studied in more detail currently. This fogging may preclude the determination of background brightness from the film due to a lack of sensitivity.

The photometer section of the system is capable, in the configuration used on these flights, of measuring brightness levels, B , between $B/B_o = 2.972 \times 10^{-15}$ and $B/B_o = 5.53 \times 10^{-12}$, where B_o is the solar brightness. The primary sources of error in the measurement are high voltage to the photomultiplier tube (PMT) and integration time, which were measured during the mission. It is estimated that the error in PMT gain due to the uncertainty of the high-voltage value is approximately 10 percent, and the integration time is known to ± 1 sec. Therefore, the error in the background brightness measurement is $\Delta(B/B_o) = \pm 1.04 \times 10^{-14}$ for the longest exposure recorded; i.e., about $t = 80$ sec, or $B/B_o = 6.9 \times 10^{-14}$. The more typical sky observations at Sun angles greater than 90 deg (or nighttime) show B/B_o to be in the 10^{-13} range. This is consistent with measurements from Apollo 15 and 16 as well as Skylab, and this is also on the order of the natural sources; e.g., unresolved stars, zodiacal light, etc.

TABLE VI-1. STS-9 OBSERVED PARTICLE CONCENTRATIONS

Number of Particles/ Frame	Number of Frames	Percentage of Potential Contamination Frames
$X \geq 10$	192	19
$10 > X \geq 2$	179	17
$X = 1$	142	14
$X = 0$	515	50%
Total Contamination	513	50%

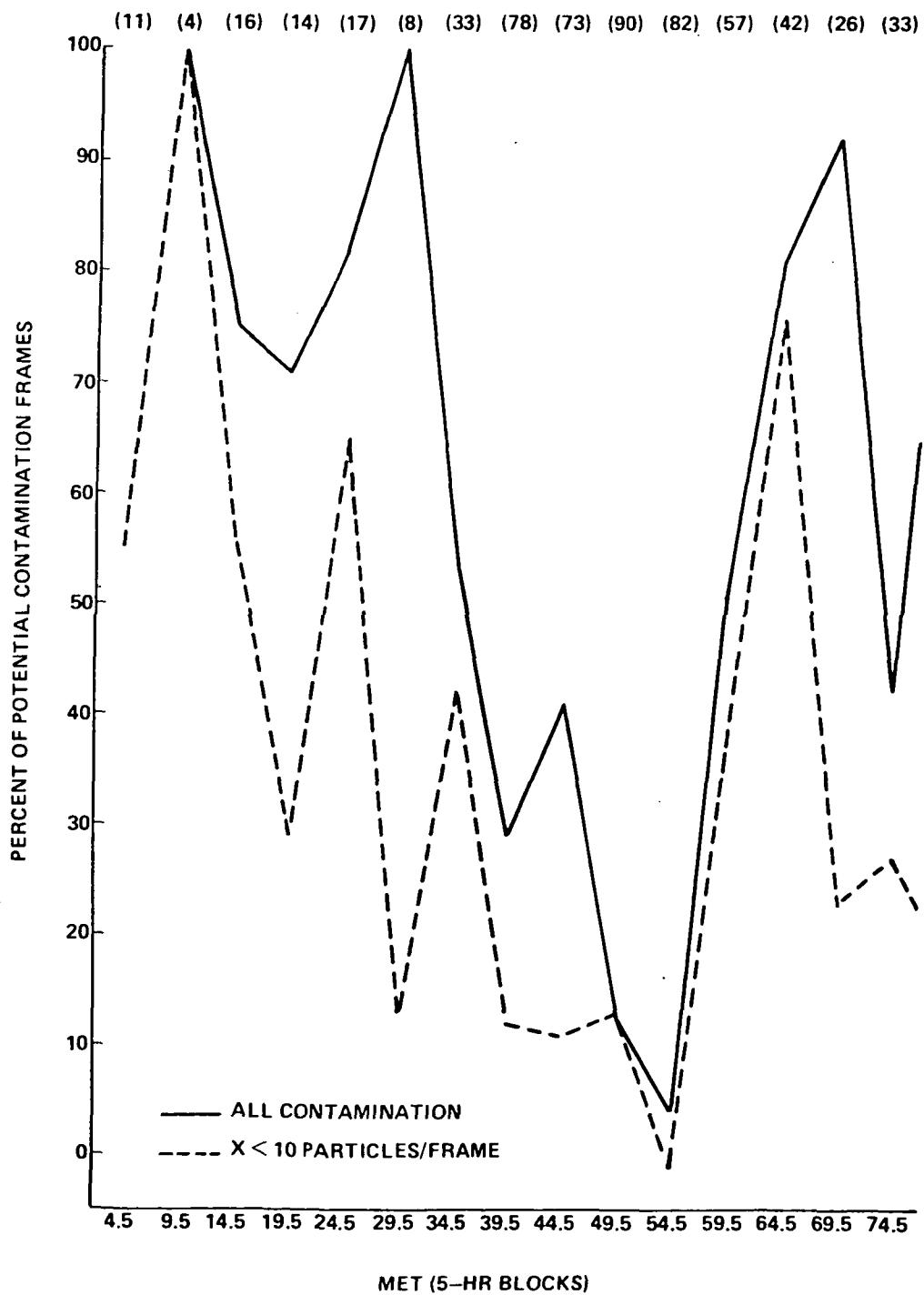


Figure VI-1. Correlation of observed contamination with mission elapsed time (MET) taken in 5-hour blocks. Contamination is portrayed as a percent of those frames capable of showing contaminant particles. Numbers at the top of the figure indicate the size of the data sample (number of potential contamination frames obtained) during each 5-hour period.

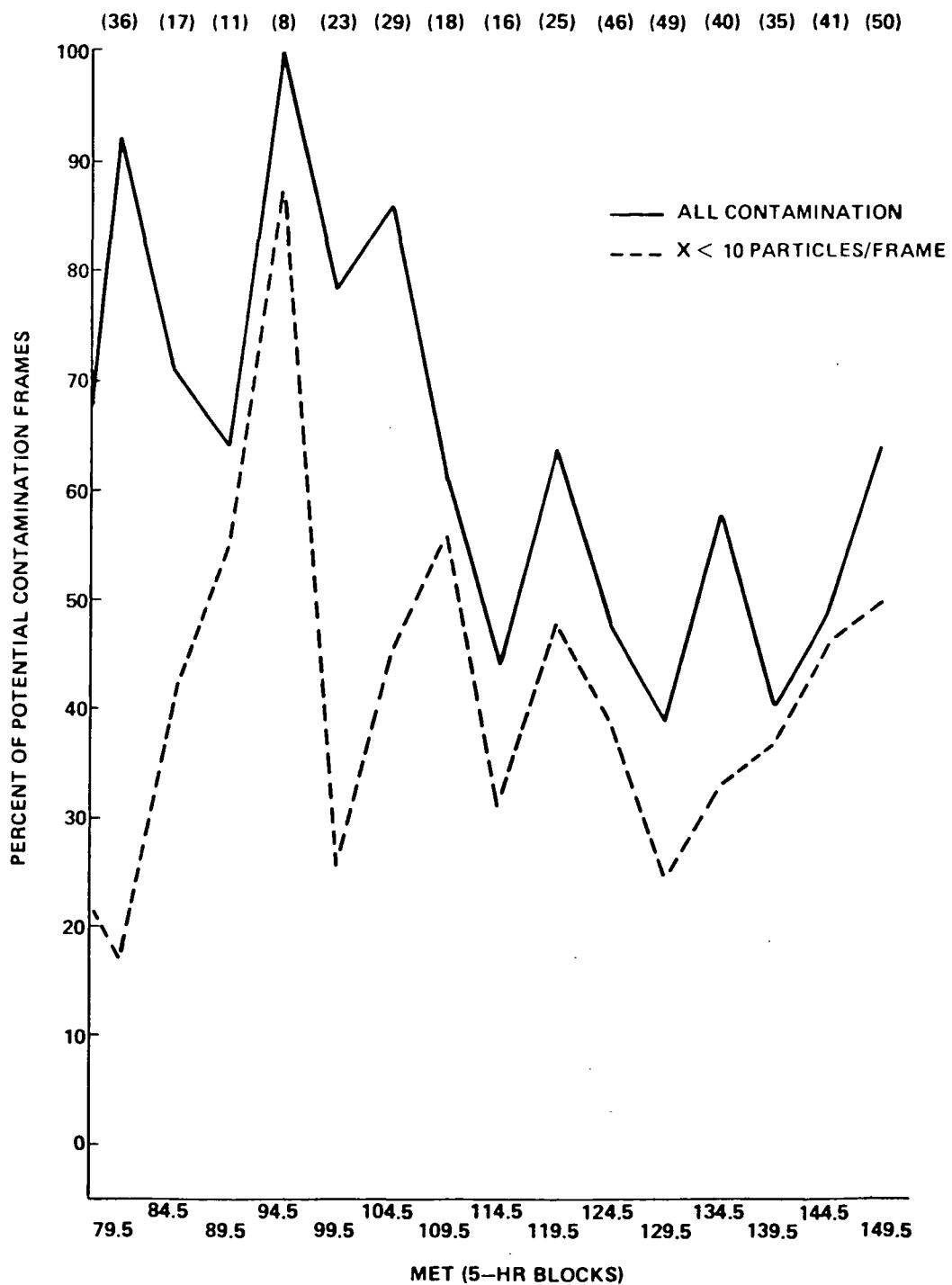


Figure VI-1. (Concluded)

VII. MASS SPECTROMETER

By G. R. Carignan* and E. R. Miller

INTRODUCTION

The IECM Mass Spectrometer, SN 2 analyzer with SN 1 electronics was prepared during August and September 1982 and delivered to the IECM in early October, 1982. This is the same system that was flown on STS-3 where it performed well throughout the duration of the mission. The instrument was recalibrated; the sensitivity was unchanged within the uncertainty of the calibration accuracy.

The mass spectrometer performed well from turn-on until about 175 hours MET. During the low temperature excursion (Fig. VII-1) the instrument was slightly detuned moving a given amu toward a lower value. Thus, for example, the water peak nominally at mass 18 can be seen influencing the mass 17 peak with some transmission loss at mass 18. This condition obtained from about 40 to 80 hours MET. Very little, if any, data are lost as a result of this problem but the data reduction process becomes more complicated.

The field of view of the mass spectrometer included the orbiter aft bulkhead and the SEPAC monitor TV. It appears that some of these surfaces were the source of significant direct streaming contaminants into the mass spectrometer which tend to mask the scattered contaminants whose flux into the mass spectrometer is reduced by the differential scattering cross sections. The algorithms for relating measured source densities to column densities of contaminants which appeared to work well for the flights of STS 2, 3 and 4 require major modification for the SL-1 geometry.

Despite these limitations, a preliminary analysis of the mass spectrometer measurements yields the following results.

PRELIMINARY RESULTS

The location of the instrument in the cargo bay viewing, as it did, several direct sources of contamination greatly complicates the quantitative interpretation of the results. However, the following preliminary results are reported.

Principal Contaminants

The measurement of H_2O is emphasized by the IECM program. About half of the available time is devoted to sampling 18 amu. The column density of water calculated from the source density had an upper limit of 2×10^{12} molecules cm^{-2} . This value decreased to about 1×10^{12} during the cold interval between about 40 and 70 hours MET. There is a pronounced increase of about a factor of 3 in source density at about 170 hours MET when the temperature of the IECM rose dramatically to about 70°C. The interpretation of this rise is not clear; it may be an increase in surface desorption on the hot walls of the instrument. It is probably a combination of increased desorption from payload bay and instrument surfaces. The TQCM's viewing these surfaces detected a large increase in adsorption during this time (Section V).

*University of Michigan, Space Physics Research Laboratory.

As was the predominant experience on the previous three flights, increases in return flux during Flash Evaporator System (FES) operations and during water dumps were insignificant.

A large, and unambiguous, helium contaminant is seen throughout the flight. Even with the instrument pointing into the Shuttle wake, the signal is seen which can only be explained by a line of sight source. Moreover, because the zirconium oxide getters which enable the collimation do not pump helium, it is not possible to compute the column density. The partial pressure of helium at the instrument was, however, in the vicinity of 10^{-9} Torr. Atmospheric helium could be observed above this contaminant background at small angles of attack. Argon behaved in a similar way to helium suggesting that it was about a 1 percent impurity in the helium source.

A large contaminant of nitrogen is also observed. It is estimated that a column density of 6×10^{12} molecules cm^{-2} is present, but this estimate is highly uncertain because of the direct streaming component. This level is fairly constant throughout the flight except for intervals when ambient atmospheric nitrogen drives the source density to higher levels. Two of the pallet science instruments provided sources of nitrogen.

There are contaminant molecules of high mass number present. Two compounds have been identified. These are $\text{C}_2\text{Cl}_2\text{F}_4$ (Freon 114) which was leaking from the Space-lab freon coolant loop at a rate of $6.2 \text{ cm}^3 \text{ day}^{-1}$, and C_2F_4 (Tetrafluorethene). Other hydrocarbon fragments do appear but these have not been identified with certainty. The abundances of these heavy molecules is a factor of more than 100 below that of the H_2O contaminant.

SUMMARY

The gases observed by the Mass Spectrometer are, for the most part, those with molecular weight below about 50 amu. The various contributors (contaminant, atmospheric, and background) are given below:

Mass 1 - Hydrogen atoms, entirely the product of dissociative ionization of hydrogen-bearing species, notably H_2O , the ionization of which yields significant 1 and 17 fractions.

Mass 2 - Molecular hydrogen which is almost entirely background of the zirconium oxide getters. No significance can be attached to this measurement.

Mass 3 - Statistically insignificant (SI).

Mass 4 - Helium. This measurement provides a good indicator of atmospheric helium abundance. Angle of attack excursions are clearly seen as is the diurnal variation in helium seen as a modulation with the period of the orbit. Helium is also a major contaminant at the instrument on SL 1.

Mass 5 - SI

Mass 6 - SI

Mass 7 - SI

Mass 8 - SI

Mass 9 - SI

Mass 10 - SI

Mass 11 - Small but statistically significant, probably a minor contaminant containing boron, possibly borane.

Mass 12 - All carbon-containing molecules contribute to this peak.

Mass 13 - Mostly a product of dissociative ionization of CH_4 . This peak together with 14, 15, and 16 is used to separate methane from other gases contributing to these various peaks.

Mass 14 - A complex sum of doubly and dissociative-ionized N_2 , double ionized CO, and dissociately-ionized CH_4 . Its amplitude is heavily modulated by angle of attack because of the N_2 contribution and also modulated by methane-producing events.

Mass 15 - Almost exclusively from methane; a very small fraction from the 15 isotope in nitrogen compounds. It is a good mass for measuring the methane because it is uncontaminated by oxygen atoms and is almost equally sensitive to methane.

Mass 16 - Methane and oxygen atoms. Ambient atomic oxygen does not survive the many surface collisions before ionization. It forms other molecules, CO and CO_2 and O_2 . The contribution to the 16 peak is thus indirect through dissociative ionization of oxygen-bearing molecules. Methane is an instrument background gas but it is known that monomethyl hydrazine is catalytically converted to methane by zirconium oxide. It is suspected that unburned thruster fuel is a source of the methane peaks observed during thruster firings.

Mass 17 - Dissociatively-ionized H_2O ; i.e., OH^+ ; amplitude is about 40 percent that of mass 18.

Mass 18 - Water. The density of H_2O in the ion source is the sum of the instrument background and contaminant H_2O backscattered by the atmospheres into the instrument orifice.

Mass 19 - A statistically significant but unknown contaminant. It is possibly a fluorine compound, but the associated spectral peaks have not been identified.

Mass 20 - Mostly doubly-ionized argon with a small H_2^{18}O contribution.

Mass 21 - Statistically insignificant except during gas calibration.

Mass 22 - Doubly-ionized CO_2 except during gas calibration.

Mass 23 - SI

Mass 24, 25, 26, and 27 - An instrument contaminant of unidentified origin.

Mass 28 - Molecular nitrogen-ambient and contaminant, and carbon monoxide which is a relatively large instrument background probably from the zirconium oxide getters but also from the instrument surfaces. Because the getters pump N_2 and degas CO, the analysis of the 28 peak at angles of attack other than near zero is very complex. At small angles the results are dominated by ambient atmospheric N_2 , and the numbers are consistent with atmospheric models.

Mass 29 - Mostly ^{14}N ^{15}N .

Mass 30 - Presumed to be NO.

Mass 31 - Not analyzed.

Mass 32 - Molecular oxygen mostly of atmospheric origin through the recombination of atomic oxygen.

Mass 33 - SI

Mass 34 - Not analyzed; partly O^{16} O^{18} .

Mass 35 - Chlorine fraction from a higher mass molecule.

Mass 36 - An unknown minor contaminant, possibly HCL, plus a small component of ^{36}A .

Mass 37, 38, 39, 41, and 42 - Small but statistically significant peaks characteristic of propene.

Mass 40 - Mostly atmospheric argon.

Mass 44 - CO_2 . Mostly instrument background with some small contribution from Shuttle environment - too small with respect to background to quantify.

Masses 50, 81 and 100 - Fractionation spectrum of $C_2 F_4$.

Masses 85, 87, 101, 103, 135 and 137 - Fractionation spectrum of $C_2 Cl_2 F_4$.

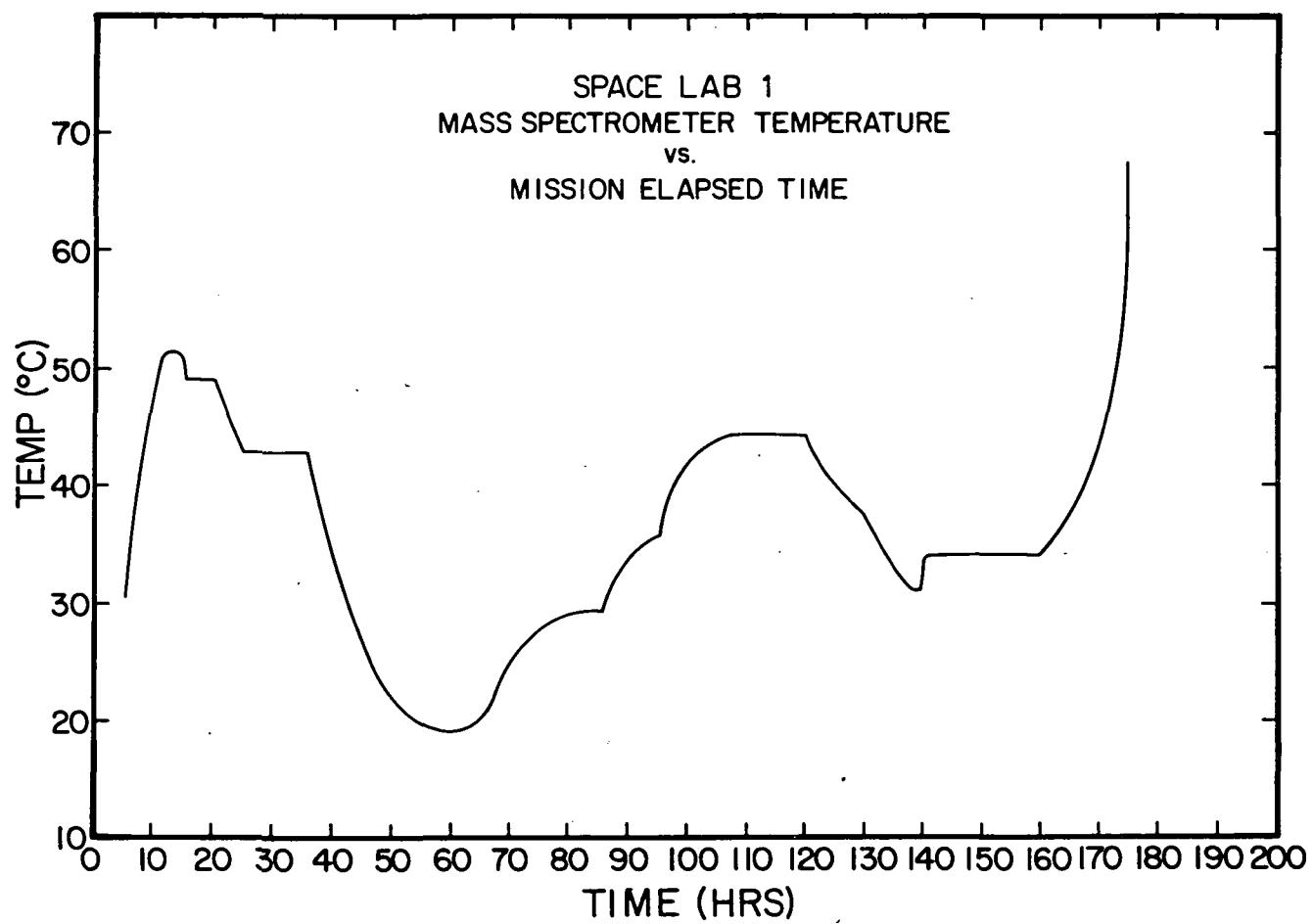


Figure VII-1. Spacelab 1 mass spectrometer temperature versus mission elapsed time.

VIII. SUMMARY

The IECM has provided quantitative results of induced contamination from the combination of the Space Shuttle and a large multidiscipline payload comprising Spacelab 1.

Beginning with measurements of particulate accumulation in the O&C facility more than a year prior to the flight, the data indicate product cleanliness levels of about 300 for exposed surface. Surfaces exposed in the OPF accumulated particulates to levels of 500-750 while the flight samples indicated level 500. The cascade impactor did not accumulate enough particulate mass during ascent to respond.

The on orbit particulate levels indicate some early mission decay. Subsequent peaks are seen, one of which may be statistical and one remains unexplained. The data presented include the many water dumps occurring during the mission. Significantly, 50 percent of film frames with conditions suitable for detection of particles are devoid of sightings.

Molecular contamination effects were not detectable on samples exposed in the ground facilities. The air sampler results from the OPF indicate typical hydrocarbons found in the urban environment with some additional substituted aromatic hydrocarbons, such as xylenes. The ascent air sample indicated the presence of unresolved hydrocarbon type material typical of lubricating oils. No evidence is seen of HCl ingesting into the cargo bay during ascent.

Indication that molecular contamination occurred during the mission is apparent from optical and auger measurements on the gold PSA sample and on the OEM fused silica diffuse sample. Also, the OEM samples with carbon and osmium coating transmittance did not change appreciably during the flight, possibly indicating contaminants on the surfaces providing protection from atomic oxygen reactions.

Directional molecular deposition measurements on constant 0°C surfaces were provided by the TQCMs. Continuous mass accretion, greatly influenced by the cargo bay temperatures, was detected by the +X sensor. Due to its location the +X sensor viewed the Spacelab pallet and instruments mounted forward of the IECM, with little view to space. Contrasted with the +X sensor is the small amount of contaminant accumulated by the -Z space viewing sensor. The ±Y and -X sensors accumulated mass during the initial heating of the cargo bay and subsequently lost mass until the "hot case" beginning at ~170 hr MET.

It is emphasized that the optical samples and QCM sensors have almost hemispherical acceptance to direct or return flux. Also, the location of the IECM and the location of the sensors on the IECM provided greater direct viewing of the spacecraft rear bulkhead and Spacelab instruments for the PSA and OEM than for the -Z TQCM.

The mass spectrometer, with its 0.1 sr field-of-view (for pumpable gases) also suffered from direct molecular streaming, allowing only upper limits of water column density determinations ($1-2 \times 10^{12} /cm^2$). Nitrogen column density upper limit levels were about $6 \times 10^{12} /cm^2$, with some probable contributions from Spacelab instrument sources. The partial pressure of helium was about 10^{-9} Torr. The total quantities of heavy masses (>50 amu) detected were more than 100 less than water and consisted of mostly Freon 114 and Tetrafluoroethene. Other hydrocarbon fragments are evident but have not been specifically identified at this time.

APPROVAL

INDUCED ENVIRONMENT CONTAMINATION MONITOR — PRELIMINARY
RESULTS FROM THE SPACELAB 1 FLIGHT

Edited by E. R. Miller

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.



A. J. DESSLER
Director, Space Science Laboratory